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EXECUTIVE OVERVIEW AND DETAILED SUMMARY

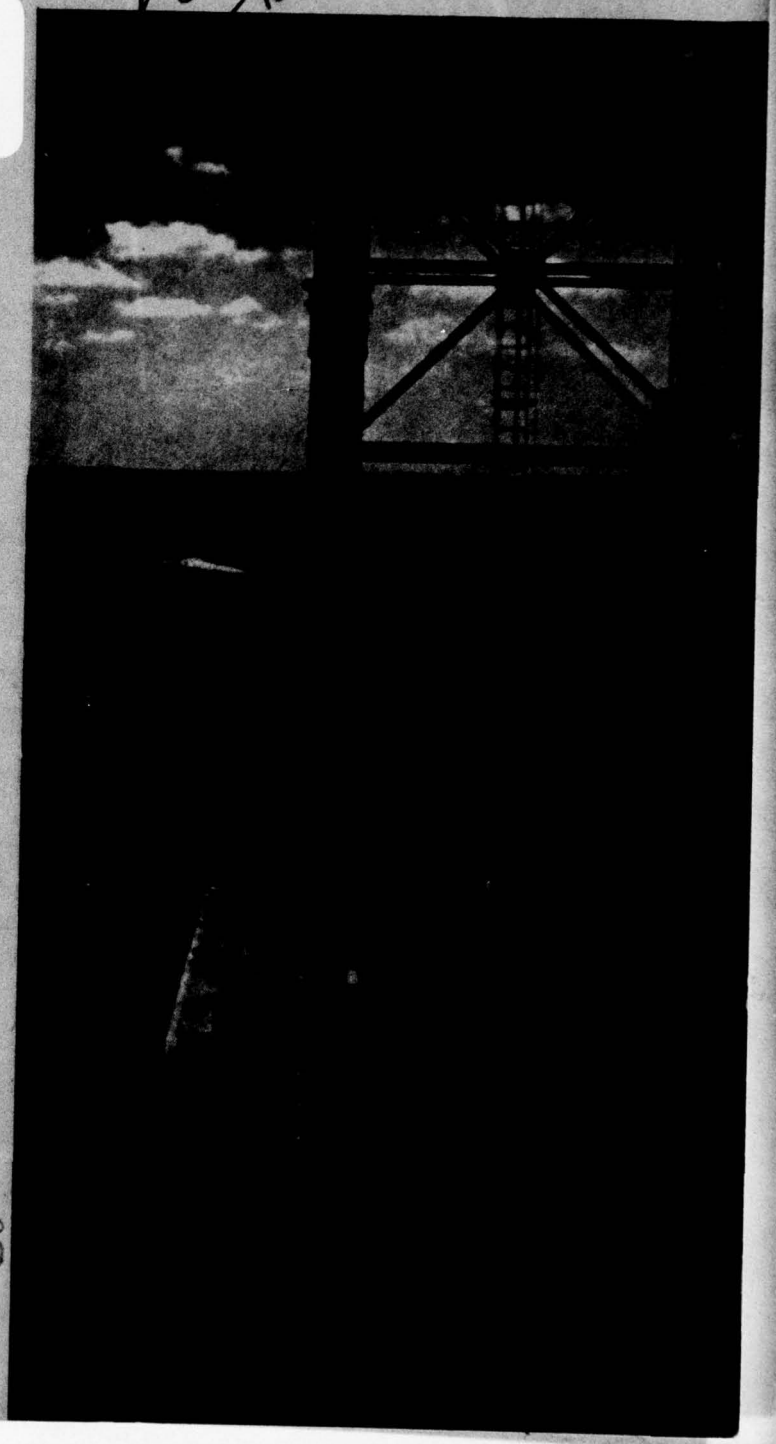
SYNTHESIS OF RESEARCH RESULTS

LEVEL A

DREDGED MATERIAL RESEARCH PROGRAM

TECHNICAL REPORT DS-78-22

EXECUTIVE OVERVIEW AND DETAILED SUMMARY



December 1978
Final Report

Prepared for
Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

THE DMRP SYNTHESIS REPORT SERIES

Technical Report No.	Title
DS-78-1	Aquatic Dredged Material Disposal Impacts
DS-78-2	Processes Affecting the Fate of Dredged Material
DS-78-3	Predicting and Monitoring Dredged Material Movement
DS-78-4	Water Quality Impacts of Aquatic Dredged Material Disposal (Laboratory Investigations)
DS-78-5	Effects of Dredging and Disposal on Aquatic Organisms
DS-78-6	Evaluation of Dredged Material Pollution Potential
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DS-78-9	Assessment of Low-Ground-Pressure Equipment in Dredged Material Containment Area Operation and Maintenance
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Recognizing a need for a comprehensive nationwide research program on the effects of dredged material disposal, Congress authorized and the Corps of Engineers accomplished the Dredged Material Research Program (DMRP). Over 250 individual studies were conducted between 1973 and 1978 at a cost of $32.8 million. In contrast to previous largely site-specific project investigations, these studies were generic in nature with the intent of developing methods of predicting effects before a project is carried out. Results of conceptual and laboratory studies were tested in the field under actual project conditions to improve the applicability of the predictive capability.

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20. ABSTRACT (Continued).

Specific goals of the DMRP were to define the water quality and biological effects of open-water, upland, and wetland disposal; improve the effectiveness and acceptance of confined land disposal where it is a desirable alternative; test and evaluate concepts of wetland and upland habitat development using dredged material; and develop and test concepts of using dredged material as a productive natural resource. The large volume of information generated in pursuit of these goals has been transmitted to Corps operating elements in various formats, incorporated into formal directives, and used extensively in the criteria and guidelines established for regulatory programs.

The most significant overall conclusion to be drawn from the DMRP is that no single disposal alternative (e.g., open-water disposal, confined upland disposal) is presumptively suitable for a geographic region or group of projects. What may be desirable for one project may be completely undesirable for another; consequently, each project must be evaluated on a case-by-case basis. In addition to this, each project evaluation must be made in full consideration of long-term as well as short-term disposal needs and possible interactions among projects. Each must be compatible with long-range regional planning.

Regarding the effects of open-water disposal, studies concluded that, unless the dredged material was highly contaminated, physical impacts are likely to be of greater potential consequence than chemical or biological impacts. Serious short-term water quality effects are not likely unless the disposal site is geochemically dissimilar to the dredging site. Biological effects of an adverse nature are similarly unlikely due to the resiliency of most organisms (except in larval stages) and the demonstrated ability of many organisms to rapidly recolonize disposal sites. Over a longer term, certain aquatic organisms will uptake chemical contaminants; however, the patterns of uptake still remain unpredictable. Except in coral areas and during times of fish migrations and spawning activities, turbidity is much more likely to be only an aesthetic problem rather than a biological problem. Irrespective of this, certain turbidity control measures are feasible under certain circumstances as indicated by field tests.

Confining dredged material on land can offer increased environmental protection, but it is not an alternative without problems and is not always beneficial. Soil biochemical conditions in diked containment areas sometimes can enhance rather than retard contaminant release; thus effluents and leachates must be carefully evaluated as to their potential effects. Where confined sites are desirable, they can be improved greatly over present practice in terms of design, construction, operation, and management as a result of DMRP research results. Particular areas of improvement include effluent regulation, storage capacity, dike design, and internal environmental conditions and aesthetics.

Several major DMRP field test and demonstration projects have proven the viability of using dredged material to develop both wetland and upland wildlife habitats in a variety of environmental situations. As a result of specific studies, guidance is now available as to what species to plant for a desired habitat, how and when to plant them, how to place and protect the dredged material, and what subsequent site management may be necessary. Additional information was generated on the relative productivity of various marsh plant species (data important in determining relative wetland-area values), the recovery of species buried by disposal, factors involved in ecological succession, and methods of predicting the possible uptake of chemical contaminants by marsh plants.

Concepts for using dredged material productively as a natural resource were explored with emphasis placed on analyzing known constraints such as transportation modes, public perception, legal and institutional factors, and economics. Demonstration tests were conducted of dredged material usage for shrimp mariculture and strip mine reclamation and the use of dredged material for agricultural soil improvement and in solid waste management was investigated conceptually and in the laboratory.

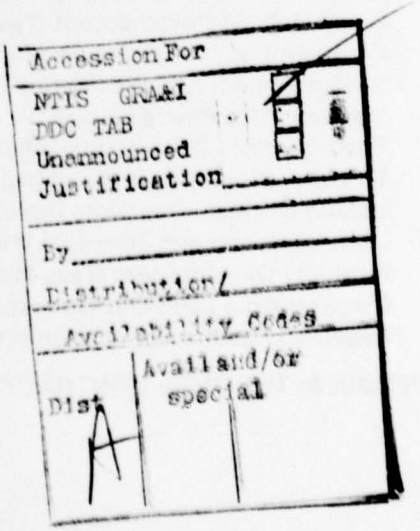
PREFACE

This report contains two elements (Executive Overview and Detailed Summary) of the six-element structured approach to presenting the results of the Dredged Material Research Program (DMRP) to a large and varied audience. The 11-page Executive Overview is intended to give the higher level managers and supervisors a ±20-minute exposure to the more important findings on the research and insight into their significance. The Detailed Summary is intended as a general reference and guide to all aspects of the DMRP and should be particularly useful to those with only limited knowledge of the DMRP.

A series of 21 Synthesis (or summary) Reports constitute the third element in presentation of results (see inside of front cover), designed for those who want an overview of the technical findings of the major DMRP tasks. The fourth element consists of the 198 Technical Reports and Miscellaneous Papers that contain all data and results in detailed form. As a reference to these two elements, the separately published Publication Index and Retrieval System constitutes the fifth element. The last element includes the 55 Information Exchange Bulletins published approximately monthly to provide interested persons with up-to-date highlights of recently completed studies and notes and news of widespread interest.

This report was prepared by the staff of the DMRP, which was assigned to the Environmental Laboratory (EL) of the U. S. Army Engineer Waterways Experiment Station (WES), Vicksburg, Mississippi. Principal contributions and supervision were provided by Dr. R. T. Saucier, Special Assistant for Dredged Material Research, and the four DMRP Project Managers, Mr. C. C. Calhoun, Jr., Dr. R. M. Engler, Mr. T. R. Patin, and Dr. H. K. Smith. Major contributions to the design and content of this report were also made by the Technical Communications Group of the EL under the direction of Ms. D. P. Booth. All work was accomplished under the direction and general supervision of Dr. John Harrison, Chief of EL.

Commander and Director of WES during the preparation of this report was COL J. L. Cannon, CE. Technical Director was Mr. F. R. Brown.



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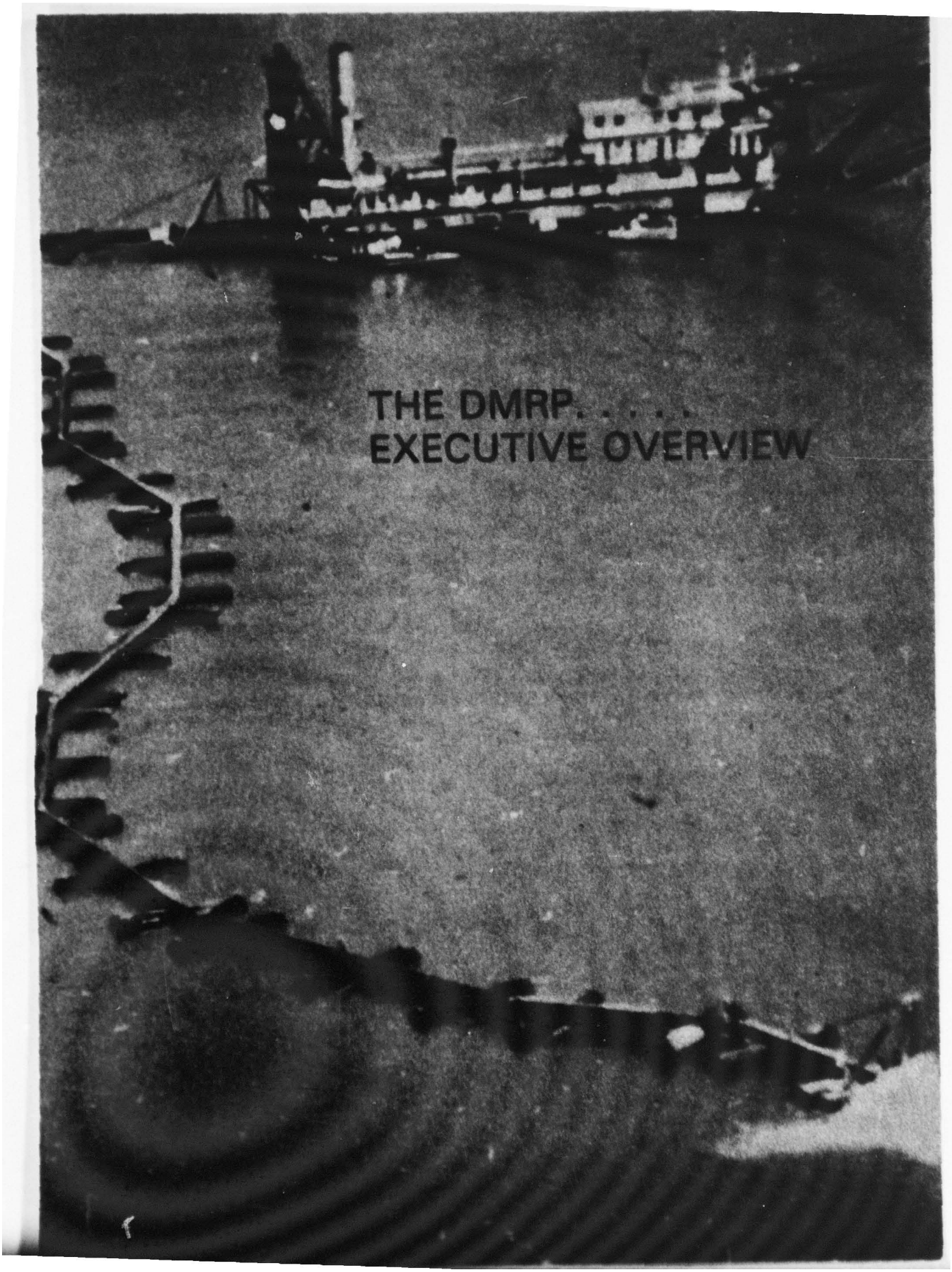


THE DMRP. . . . .
EXECUTIVE OVERVIEW

At the beginning of this decade, the concern over the environmental impacts of dredging to maintain navigable waterways and harbors and the disposal of the dredged material reached the stage where Federal legislation was necessary. However, it was recognized that the technical base on which the initial legislation was based was inadequate—existing information was limited to site-specific studies that permitted only inferences that the open-water disposal of polluted dredged sediments presumably must be harmful to the environment. It was in this context that the need for a comprehensive nationwide research program was recognized and authorized by Congress (Public Law 91-611).

Responding to this need for more basic information on all types of dredged material disposal and possible alternatives to existing methods, the Corps of Engineers undertook the Dredged Material Research Program (DMRP) via the Waterways Experiment Station in Vicksburg, Mississippi. Initiated in 1973, the DMRP was accomplished in the planned 5-year time frame at a cost of $32.8 million. Highly interdisciplinary in nature, it was a tightly managed, basically contracted (70% of total research funds), extensively coordinated effort involving more than 250 individual studies. These consisted of a planned and phased mixture of conceptual, laboratory, and field studies in association with routine Corps projects designed to understand the processes and mechanisms involved in environmental impacts. To an extent not possible previously, this generic approach was intended to permit the development of much-needed methods for predicting effects before a project is carried out or a permit issued under regulatory functions.

The DMRP was designed to be as broadly applicable as possible on a national basis with no major type of dredging activity or region or environmental setting excluded. It thus resulted in methods of evaluating the physical, chemical, and biological impacts of a variety of disposal alternatives—in water, on land, or in wetland areas—and produced tested, viable, cost-effective methods and guidelines for reducing the impacts of conventional disposal alternatives. At the same time, it demonstrated the viability and limits of feasibility of new disposal alternatives, including the productive use of dredged material as a natural resource.

Before summarizing the more significant findings of the DMRP, it is important to note that extensive efforts were taken to ensure effective information dissemination and technology transfer. In addition to a wide variety of publications designed to meet the varying requirements of different audiences, the technical staff that managed the DMRP repeatedly briefed Corps and non-Corps personnel at all levels throughout the nation and participated in several interagency coordinating and planning committees. Of greater significance were the efforts to incorporate research results into Corps regulations and operating procedures and into the criteria and guidelines developed for regulatory programs. In the latter case, both the Section 103 (Public Law 92-532) and 404 (Public Law 92-500) programs for ocean and inland water

protection have profited from results of the DMRP and will continue to do so as efforts progress to prepare technical implementation manuals for both programs.

To those concerned with national or regional planning and policy formulation, there are two extremely important fundamental conclusions that can be drawn from the DMRP. The first is that there is no single disposal alternative that presumptively is suitable for a region or a group of projects. Correspondingly, there is no single disposal alternative that presumptively results in impacts of such nature that it can be categorically dismissed from consideration. Put in different terms, there is no inherent effect or characteristic of an alternative that rules it out of consideration from a technical standpoint prior to specific on-site evaluation. This holds true for open-water disposal, confined upland disposal, habitat development, or any other alternative.

Specific on-site evaluations mean that each project must be considered on a case-by-case basis. It is not technically sound, for example, to make the general statements that ocean disposal must be phased out or that all material in the Great Lakes classified as polluted must be confined behind dikes. To do this would be contrary to research results that have indicated that there can be situations where there is greater probability of adverse environmental impacts from confined disposal than from open-water disposal. Yet, in other situations such as when certain types of contaminants are present, confined disposal may provide the greatest amount of environmental protection.

Implications of this conclusion from a management point of view are fully recognized. Case-by-case evaluations are time consuming and expensive and may seriously complicate advanced planning and funding requests. Nevertheless, from a technical point of view, situations can be envisioned where tens of millions of dollars may have been or could be spent for alternatives that contribute to adverse environmental effects rather than reduce them.

The second basic conclusion is that environmental considerations are acting more strongly than possibly any force to necessitate long-range regional planning as a lasting, effective solution to disposal problems. No longer can disposal alternatives be planned independently for each dredging operation for multiple projects in a given area. While each project may require a different specific solution, the interrelationships must be evaluated from a holistic perspective and thought given to when particular disposal alternatives may have to be replaced with others as conditions change. Regional disposal management plans not only offer greater opportunities for environmental protection ultimately at reduced project cost, but also meet with greater public acceptance once they are agreed upon.

Considering first the specific findings with regard to the effects of open-water disposal, the physical effects—the logical and easily predicted physical effects—are with few exceptions more important than chemical or biological effects. Physical effects include the smothering of a clam bed, the disruption of

a flow pattern, a change in salinity, or a similar effect. These possible consequences of disposal operations are persistent, often irreversible, and compounding. However, they are infrequent and can be avoided with the judicious application of evaluative procedures available under guidance for the Section 404 and 103 programs. More intense evaluations of physical impacts traditionally have relied on physical hydraulic models, but the DMRP developed mathematical models that can also be used for certain needed predictions. Specifically, a partially verified and tested math model is now available to predict the short-term fate or dispersion of barge and hopper dredge dumped material as well as pipeline dredged material in ocean, estuarine, lake, and river environments. An unverified sediment transport model for the long-term and ultimate fate of these deposits is now available.

Contrary to much public, scientific, and governmental opinion, the deep ocean, when analyzed in a detailed objective fashion, is not everywhere a fragile environment totally unacceptable for dredged material disposal. A significant contract study concluded that, should the economic and technological aspects be favorable, extensive deep ocean areas are more environmentally acceptable for disposal than are some highly productive continental shelf areas, especially for contaminated materials.

Turning to inland and coastal areas, the DMRP achieved definitive results that soundly substantiate that most widely held fears over the short-term release of contaminants to disposal site waters are unfounded. As long as the geochemical environment is not basically changed, most contaminants are not released from the sediment particles to the water. However, in contrast, upland disposal often does result in a change in the geochemical environment that can lead to contaminant release. Some nutrients such as ammonium and manganese and iron are released in open-water disposal, but in most cases enough mixing is present to rapidly dilute these to harmless concentrations. Situations where toxic effects could occur would most likely be where pipeline dredges are discharging large volumes of material into very shallow estuarine waters.

The difficult problem of the effects of turbidity or suspended sediment particles on both water quality and aquatic organisms was addressed with significant results. It was found that, except in unusually environmentally sensitive areas such as coral reefs, turbidity is primarily a matter of aesthetic impact rather than biological impact. It is, of course, often advisable to schedule dredging and disposal operations to avoid disrupting spawning activities and fish migrations. However, studies showed that most adult organisms can tolerate turbidity levels and durations far in excess of what dredging and disposal operations produce. These studies, conducted in the laboratory and verified in the field, involved a variety of marine, estuarine, and freshwater organisms.

With regard to benthic or bottom-dwelling organisms, their resiliency, once

beyond the larval stage, was demonstrated. Disposal sites can be and are rapidly recolonized by the establishment of new populations, by migration of organisms from adjacent unaffected areas, and by survival of the organisms buried. Colonization by opportunistic species can occur within weeks and by the original species within months. When the type of dredged material disposed at a site is of the same grain-size distribution as the natural bottom (e.g., sand deposited on sand or silt on silt), survival of existing organisms is maximized. Conversely, a mismatch of sediment type can be quite detrimental. The condition that could be most injurious to benthic organisms is when the disposal operations, primarily hydraulic pipeline operations, produce a fluid mud or "fluff" layer that is a difficult and alien environment for many organisms.

It was shown that certain aquatic organisms will uptake chemical contaminants from dredged material. However, the patterns of uptake were found to be unpredictably erratic and there were no clear trends.

Different types of organisms will uptake different quantities of contaminants such as heavy metals depending on an apparent variety of environmental and biological factors. The complexity of this process and the low level of predictive capability have been controlling factors in the decisions that bioassays must be an integral part of the evaluative criteria used in implementing the Section 404 and 103 programs. It is fully realized that bioassay tests are expensive and time consuming, but the state-of-the-art allows no effective alternative for determining how organisms will be affected by contaminated dredged material.

Determining the effects of open-water disposal has been somewhat like trying to strengthen a chain. Once the weakest link is found and strengthened, attention is necessarily then directed to the next weakest link. Major DMRP field studies of open-water disposal sites strengthened several links. They verified several major laboratory findings and showed that short-term impacts are quite brief and are not of major environmental significance. These indeed can occur, but are certainly going to be the exception rather than the rule. In addition, studies have called attention to situations where open-water disposal has even had beneficial environmental effects and have identified operational procedures that can be used to reduce impacts without new technology or major cost increases.

The next weakest link in the strengthened chain involves long-term biological impacts. Certain selected field test sites will be monitored for 3 years beyond the end of the DMRP to provide some much-needed information on this subject; however, many answers still will not be forthcoming. Among these will be ones relating to chronic or sublethal effects of very long-term exposure of benthic organisms to contaminated material and effects on reproduction.

Thus far, mention has been made primarily of assessing the effects of open-water disposal and very little about controlling or mitigating effects when

they occur. This aspect was not overlooked, and even when an effect was found to be an unlikely event, it was presumed there could be instances where control or regulation would be advisable for one reason or another. A good example is turbidity. Even though adverse biological effects are highly unlikely, there may be reasons why excess turbidity should be minimized. One study called attention to how simple equipment maintenance and efficient operation can reduce turbidity and another extensively evaluated and developed guidelines for using silt curtains or "diapers," pointing out when they can be effective and when they will only mask the problem and not alleviate it. For example, silt curtains are ineffective where currents exceed 1 knot and will be both ineffective and uncontrollable under moderate wave conditions.

The DMRP included considerations of dredging equipment development in very few cases as this was largely beyond its scope. However, because of the peculiar nature of the problem of turbidity, a concept was developed for the submerged discharge of material from a hydraulic pipeline dredge through a specially designed underwater diffuser. Model tests of the diffuser showed it has excellent potential for reducing turbidity as well as for reducing the extent of the potentially harmful fluid mud layer that so often develops.

On a related subject, various studies considered the feasibility of treating contaminated dredged material to reduce the impact of disposal operations. Because of the large volumes and variable nature of the material involved and the very low concentrations of contaminants, most conventional treatment processes are infeasible, particularly when considered for use in the dredging operation itself. Some processes are feasible for confined disposal facilities and are discussed later. However, with regard to open-water disposal, only in-line oxygenation to reduce the dissolved oxygen sag accompanying disposal of certain kinds of material being moved by a pipeline dredge appears operationally and economically practical. The use of flocculents to reduce turbidity in an open-water disposal situation is not effective or practical in most situations.

No studies directly addressed the issue of hopper dredge overflow as this is not a disposal problem per se. Nevertheless, program results do shed some light on this matter since turbidity from overflow is no different from that resulting from other dredging-related causes. In many, if not most, cases, this practice should result in no significant impact; however, there is an element of risk involved since the fine-grained materials overflowed are the ones that contain the relatively highest contaminant loads. The negative public image of this practice is widespread and there can be situations where aesthetic impacts are more important than biological impacts. A study of foreign dredging practices and technology showed that there is a simple and inexpensive technique developed in Japan that shows promise for significantly reducing the amount of surface turbidity associated with hopper dredge overflow.

Confined or diked containment of dredged material as a conventional alternative was also extensively investigated. Confining contaminated material on

land or in shallow water next to land can be an environmentally sound and preferred alternative, but not inherently better than open-water disposal for several reasons. There are technical reasons why confined disposal could be less effective in protecting water quality or organisms. These include the change in the geochemical environment that could lead to an enhanced release of contaminants and the difficulty in retaining the finer grained particles in environmental settings where they are likely to have greater impact when released (e.g., wetlands or small streams). Also, it should not be overlooked that confined facilities are expensive, of finite life, and result in a permanent change in the physical landscape, often in conflict with land-use and management plans.

Irrespective of the alternative decision, if a confined disposal area is to be constructed, it must be designed, built, and operated in such a way as to achieve maximum effective capacity and satisfactory effluent quality. Unfortunately, historically, neither of these basic objectives has been met by most of the facilities that have been built. These objectives are by no means mutually incompatible and the reasons they have not been met involve lack of technical knowledge as well as policy and institutional factors such as cost, funding sources, and diffused construction and management responsibilities.

The DMRP developed and issued in report and manual form a variety of guidance and information that should largely alleviate the technical knowledge limitation. No longer is it necessary to rely primarily on ''rules of thumb'' and personal experience. Specific guidelines were prepared for designing containment areas with appropriate storage capacities, surface areas, and shapes; designing and building dikes; designing and placing inflow pipes and weirs; selecting equipment for operating in disposal areas; landscaping containment areas; and controlling problems such as mosquito breeding and noxious odors.

If a confined disposal site is to be effective from an environmental protection standpoint, it must be efficient in retaining a high percentage of the finer soil particles, for it is the clays and silts that carry the contaminants. These are admittedly the materials most difficult to retain in an area, but if they can be, the effluents should be essentially nontoxic except for occasional situations where nutrient levels and oxygen depletion may be excessive.

The guidance mentioned above contains specific information on how disposal site retention times can be maximized; however, there are cases where sites are simply incapable of providing adequate retention. Addressing these situations, studies found that coagulants and flocculents can be quite effective for effluent treatment, and treatment system design and operation guidelines were developed based on actual field tests. Studies also considered the principles involved in the land treatment of wastewater and concluded from a limited field test that the regulated discharge of disposal area effluents through a natural marsh can be effective in removing nutrients.

With time, the soil physicochemical environmment in a confined disposal site can become appreciably different from that of sediments before dredging or sediments deposited in open water. The upland drained situation can lead to an oxidizing acidic environment that was shown in laboratory studies to be conducive to the leaching of contaminants, particularly heavy metals. Whether or not the leachate will contaminate groundwater will depend on the absorptive capacity of the natural soil, which is normally quite high. A far more serious and more probable impact can occur when saline sediments are placed in a freshwater upland environment. Salt will leach from most dredged material and whether or not it will contaminate groundwater must be carefully evaluated on a case-by-case basis.

In terms of time, effort, and cost, the most expensive aspect of confined dredged material disposal can be the land acquisition. The DMRP included studies aimed at alleviating or lessening this problem. These dealt with methods to increase the storage capacity of existing sites and/or concepts for making existing sites reusable.

Field tests proved that it is possible to dewater even some of the more difficult types of dredged material so that disposal sites can store more sediment and less water. A side benefit of this dewatering is improved engineering characteristics of the densified material. Through field investigations and tests, surface trenching with an available surplus Marine Corps vehicle called the Riverine Utility Craft proved to be cheap and effective in providing natural drainage. Whereas more complex and even exotic dewatering methods such as underdrainage systems and electro-osmotic dewatering may be feasible where the cost can be justified, here is a case where the cheaper technique, relying heavily on nature, was shown to be generally the most effective.

Dredged material, particularly dewatered dredged material, has value for landfilling or in construction. Every cubic yard that can be removed from a containment area and used, donated, or sold offsite for any purpose is a cubic yard of new storage capacity gained. In conjunction with the Corps Districts, concepts were developed for disposal area reuse for both existing and planned disposal sites. Numerous possibilities exist for separating and handling materials in a site, and actual field situations have demonstrated that uses within the site for purposes such as haul road construction and dike raising are too often overlooked as completely viable concepts.

Dredged material is also a substance that can be used to create or improve wildlife habitats—examples of this already exist in nearly all parts of the country. However, it is known that the past occurrences were primarily accidental rather than planned. Realizing that even the most productive habitats sometimes can be out of place within an ecosystem, the DMRP concentrated on understanding the natural processes and developing guidelines on exactly what should be done, where and when, and what are the relevant considerations in all phases from site selection to follow-up management.

Certain basic studies were concerned with wetland plant productivity from two points of view. Knowing the relative productivity of a species is one factor in selecting those suitable for planting at a habitat development project. It is also one factor in the extremely difficult problem of determining the value of a wetland being evaluated as a disposal site. Studies showed, for example, that the productivity of several so-called minor species is greater than anticipated and the ability of at least one species to recover from burial beneath dredged material up to 9 inches thick is greater than expected. This information will be helpful in selecting areas and methods of disposal should a wetland area have to be used for disposal.

Considerable attention was given to the uptake of chemical contaminants by marsh plants as an obvious concern in decisions on developing marsh habitat using dredged material. Uptake was found to occur in different ways and at different rates in most plant species, but the amounts of contaminants involved were not so large as to cause major concern. The question of how much uptake is too much was not resolved and is not likely to be anytime soon; however, evaluations of uptake should be made with an awareness of the natural functioning of a wetland system as a contaminant processor. The end product sought by the research was a test that can be used to predict the pattern of uptake from a particular type of material. To this end, it was largely, but not entirely, successful since certain contaminants have proven difficult to predict as far as behavior is concerned.

Marsh creation using dredged material is now a proven, viable alternative that can be designed and implemented as reliably as any other alternative. Also, certain misconceptions about this alternative were firmly dispelled. In particular, it can be easily demonstrated that marsh development does not necessarily eventually preclude the disposal of material from subsequent maintenance dredging projects. There are examples where phased marsh development, with or without other disposal alternatives, has been planned in such a way as to accommodate maintenance dredging for periods of 50 years or more.

While marsh development is a field-tested and proven alternative, it is not a simple one and it is often not cheap. However, costwise, it is definitely competitive with other alternatives and cheaper than some. Marsh development is not unusually difficult from an engineering point of view, but it is difficult operationally in relative rather than absolute terms. By this, it is meant that no new equipment or technology is needed, but rather dredgers are sometimes required to perform unfamiliar operations according to unusual time and accuracy specifications. The operations can be done, but they will require close coordination and cooperation.

As indicated earlier, marsh development is not a satisfactory alternative for all locations, but there is no major geographic region where it is not desirable and possible somewhere. Marshes can be developed in the Great Lakes area

and along inland river systems as well as in all coastal areas. The only known environmental conditions in which it is probably not practical are ones with high tidal ranges and strong waves and/or currents. Otherwise, depending on local conditions, marshes can be developed in a variety of shapes and sizes, with different placement methods, with different types of dredged material, with different plant species and planting techniques, and with or without retaining dikes. Specific guidance was prepared for each of these considerations and is supplemented by decision methodologies useful in selecting sites and particular habitat development goals.

In some respects, the development of upland habitats, either on new disposal sites or by reclaiming old sites, is a technology more advanced and more tested than marsh habitat development. Upland habitat includes such situations as food and cover for mammals and nesting, resting, or feeding areas for waterfowl. Most of these require only the application of existing agronomic and wildlife management practices. But availability is useless without awareness, so this information was compiled and synthesized for widespread distribution. Upland habitat development can be relatively inexpensive and is not difficult, and there are hundreds of disposal sites that could be improved environmentally and meet with greater public acceptance if improved in this way.

Small islands created by dredged material disposal in inland waterways and coastal bays and estuaries are a special type of upland habitat development. Several regional surveys showed that many of the more than 2000 of these islands have become extremely valuable wildlife habitat. In fact, maintenance of the U. S. population of several colonial nesting birds such as sea gulls, terns, and herons is dependent upon islands of this type.

Thus, island development obviously can be an environmentally beneficial disposal alternative and one that has large public acceptance. The DMRP provided guidance on how islands can be designed and managed to be of greatest value to certain target species and how the natural evolution of the islands can be controlled for maximum wildlife benefit. However, there are problems, both real and imagined. In the former category are the conflicting concerns and needs of the wildlife interests and the fisheries interests who often have opposing views on the need for islands versus open water. This type of problem can only be resolved on a case-by-case basis. In the latter category is the widespread belief that once an island is created and inhabited by desirable wildlife, it can never again be used as a disposal site. This is not true! In fact, studies showed that unless natural vegetational successional patterns are occasionally interrupted, the islands will lose their wildlife value. The most practical way of providing the needed interruption is by depositing a new layer of material. Specific guidance includes management techniques on how continued disposal can be phased with optimum wildlife use. Once again, the key is a sound management plan.

While research focused primarily on wetland and upland habitats, aquatic or submerged habitats were also included. A literature review and a small field test were accomplished, but these concluded only that it is a promising but unproven disposal alternative. It was demonstrated that seagrasses can be transplanted to a disposal site; however, much additional information will be needed before the basic requirements for establishing a successful seagrass meadow are recognized and understood.

The fourth major part of the DMRP was the development and testing of concepts for nonwildlife-oriented beneficial or productive uses of either dredged material itself or disposal sites. Perhaps more than in any other alternative, successful use of the material or the sites as a natural resource requires favorable and often fortuitous circumstances, but these do occur. Nontechnical factors outweigh technical ones more as a rule than as an exception and requirements for coordination and cooperation in land-use planning are extraordinary. Since many of the concepts are new and unusual, there is also the requirement for the Corps or some other group to take the initiative in promoting the ideas and getting people to think about them. Indeed the DMRP was a positive factor itself in advertising concepts and moderating apprehension by pointing out where others have applied the concepts successfully.

Many products such as aggregate and bricks have been made using dredged material, sometimes successfully, and the potential for new concepts is limited only by the breadth of one's imagination. However, success will be difficult in view of the quality and undependability of the supply of the raw material, the requirements for capital investment, and especially the need for favorable market conditions. The only concept with apparent potential for at least regional application that was field-tested as part of the DMRP was the use of conventional disposal sites for the mariculture of shrimp. This was proven technically feasible and has caught the attention of some private entrepreneurs who feel the potential market outweighs the risk. In this and similar concepts, the advantage is that a landowner is more likely to favorably consider the use of his land as a disposal site if he can derive some benefit from it rather than relegate it solely to a form of waste disposal. In mariculture, the disposal site forms the required impoundment and the organic-rich dredged material is a periodically renewed source of food for the organisms.

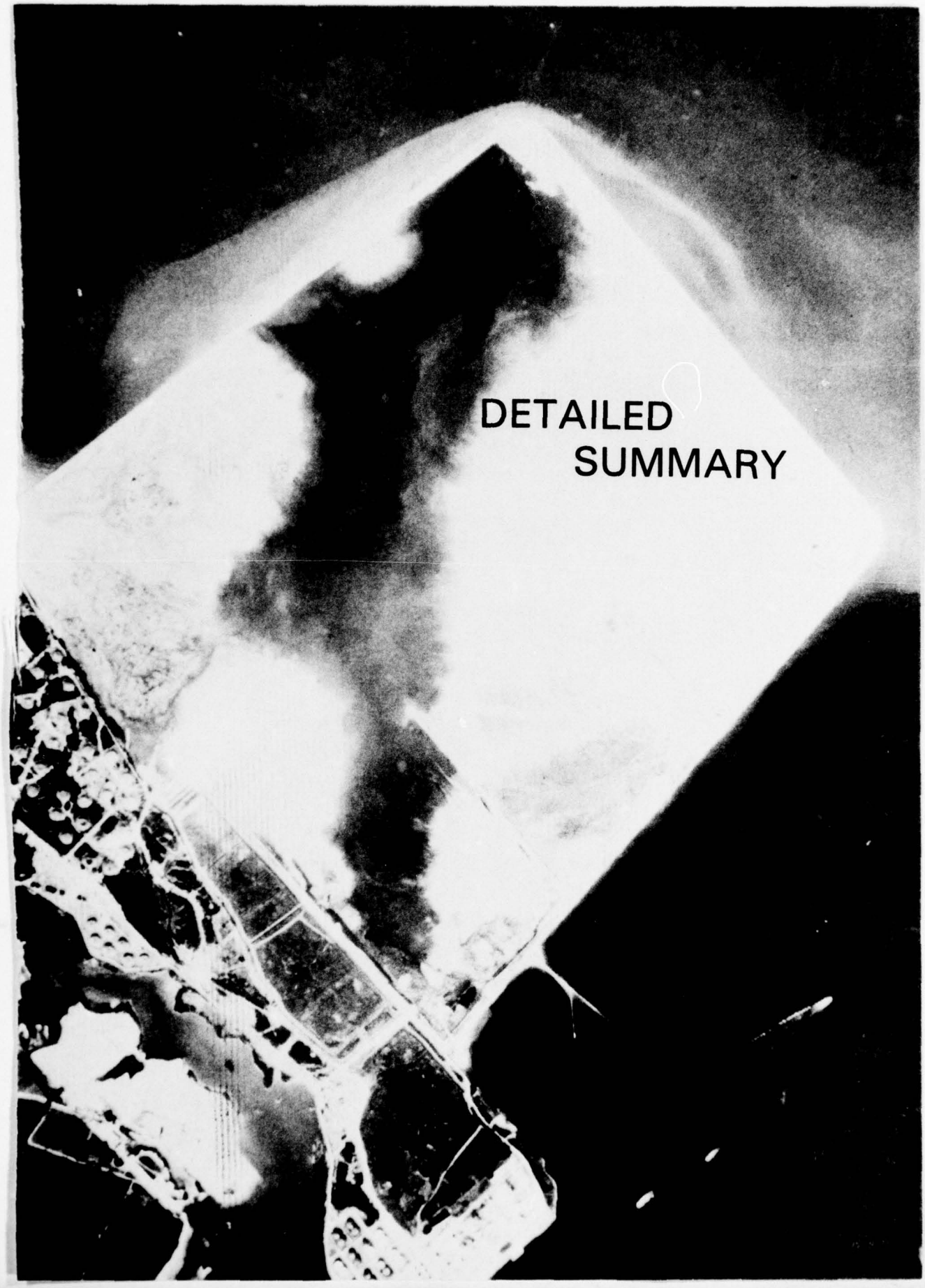
Opportunities for the productive use of dredged material increase appreciably as one moves inland from navigable waterways. As a consequence, a study considered multiple aspects of modes of long-distance transport of dredged material and produced a method to use in determining the feasibility and cost of various transport systems for individual projects. If dredged

material can be moved economically over distances of tens of miles, some of the disposal opportunities that emerge include improvement of agricultural soils, use of dredged material in solid waste management, the filling of abandoned pits and quarries, and strip mine reclamation. Reports were prepared on multiple aspects of each of these possibilities, documenting requirements and discussing case histories as well as setting forth specific concept options.

As would be expected, concerns over the effects of using chemically contaminated materials dominate the list of relevant considerations; however, so far these have not proven to be limiting. One should never lose sight of the fact that much dredged material is not contaminated, nor should one overlook the real dangers of placing saline dredged material in freshwater areas.

Considering productive uses of dredged material, the obvious value of the land created when a disposal site reaches capacity was not overlooked. Most disposal sites filled with fine-grained materials from maintenance dredging are not suitable for industrial or commercial development from a foundation engineering point of view, but they can be ideally suited for recreational development. While it is not the present policy of the Corps to expand its role in recreation to include navigation projects, there is a need for recreational facilities in this context and many non-Federal groups are interested. One study pointed out the issues related to such use of disposal sites, including funding availability, maintenance responsibility, and guarantees of public land use. Another analyzed case histories in an attempt to find out why certain productive land uses have succeeded and others have failed. These include but are not limited to recreational uses. Other studies evaluated laws and regulations at all levels impacting on land uses and determined the land values and associated benefits created by disposal sites. The end products are guidelines on how the Corps or other groups can achieve or promote the productive subsequent uses of disposal sites both for the inherent benefit of doing so and the probability of being able to acquire new sites more easily.

In summary, the DMRP contributed considerable new information that is being and can be used in all aspects of dredging project design and implementation, including project planning, engineering design, environmental impact assessment, project scheduling and operations, and permit evaluation. In other instances, it only affirmed what had been previously held by many, but it has done so in such a way as to reduce remaining doubt and enhance more widespread acceptance. In both cases, the result has been greatly increased opportunity for economically necessary waterways and harbors maintenance and development to proceed in harmony with appropriate levels of environmental protection and even enhancement in some cases.


DETAILED
SUMMARY

Administrative Aspects

AUTHORIZATION. . . . .

- By the River and Harbor Act of 1970 (Public Law 91-611, Section 123(i))
- Waterways Experiment Station (WES) assigned in May 1971 to define and assess the problems and develop the research program
- Funding for research authorized by the Office of Management and Budget (OMB) in February 1973
- WES initiated research (Dredged Material Research Program (DMRP)) in March 1973
- Budgets for continuation of research between fiscal years 1974 and 1978 approved incrementally by Congress and OMB on the basis of obtained and anticipated results
- Program completed in March 1978

OBJECTIVE. . . . .

To provide, through research, definitive information on the environmental impact of dredging and dredged material disposal operations and to develop technically satisfactory, environmentally compatible, and economically feasible dredging and disposal alternatives, including consideration of dredged material as a manageable resource.

SPECIFIC GOALS. . . . .

- Establish definitively the effects of open-water, land, and wetland disposal on water quality and organisms
- Test and evaluate concepts of marsh development and land and water habitat development as environmentally beneficial disposal alternatives
- Improve and enhance the acceptance of confined land disposal as an alternative and consider regulation of the dredging/disposal operation as an environmental control measure
- Develop and test concepts for using disposal sites for productive purposes and consider the use of dredged material as a natural resource

BACKGROUND. . . . .

In the United States, major commercial water routes measure in the tens of thousands of miles, and ports or harbors number in the hundreds. When recreational boating is included, these figures increase by an order of magnitude. Excluding the initial construction effort involved, most of these waterways and harbors require periodic maintenance since they are in situations where there is a constant conflict with geological, hydrological, and indeed even cultural processes. If these facilities are to be kept operational, they must be dredged periodically.

Modern dredges, particularly hydraulic cutterhead pipeline dredges, are among the most efficient excavation tools ever devised by man. They are the solution to keeping waterways navigable; however, they present several major problems, foremost of which is the environmentally acceptable disposal of the dredged material.

Dredged material can consist of a wide range of materials, including those contaminated by industrial, urban, and agricultural discharges and runoff. It is excavated and transported in hundreds of different locations by different methods and in a variety of different consistencies and widely varying quantities. It is disposed of in a multitude of different ways—but almost always with the view that it is a worthless by-product of a necessary activity.

Several years ago, there was evidence—but little or no scientific data to prove—that much of the nationwide concern and alarm over the environmental effects of dredging and dredged material disposal were unfounded. On the other hand, there was knowledge that adverse effects certainly could occur under certain conditions, but the extent and magnitude of the effects largely could only be guessed at. The major problem to be solved was how, considering the state-of-knowledge and the diversity of dredging locations and situations, could the significant adverse effects be *predicted* so that proper avoidance or mitigative actions could be taken where it is *reasonable* to do so?

Considering *only* Congressionally authorized Federal dredging projects, over 350,000,000 cubic yards of material are dredged each year from several hundred locations at a cost of well over $200 million. To study environmental effects with sufficient

comprehensiveness to understand cause-and-effect relationships and to identify acceptable alternatives at each of these locations would have been prohibitively expensive and beyond the scientific manpower and facility resources. Also, as Congress was aware in 1970 when it passed legislation for a multihundred million dollar interim program of mitigative measures in the Great Lakes area, a regional approach to understanding the long-term environmental consequences of a nationwide activity would not suffice. Even the most effective synthesis of individual studies of areas and concepts would not suffice for developing meaningful long-term national criteria on which applications for permits for dredged material disposal in inland or oceanic waters could be evaluated.

A holistic approach to understanding effects and identifying alternatives was endorsed as an effective way to satisfy the requirement set forth in 1970 by Congress for a comprehensive, nationwide study of dredged material disposal problems. The DMRP, completed in March 1978, provided answers and implementable alternatives to decisionmakers at all levels that should alleviate the need for most investigations beyond the usual pragmatic project-specific ones. The DMRP was not a panacea, but it brought to bear on carefully selected key problem areas an extensive and intensive combination of conceptual, laboratory, and field studies programmed to meet finite objectives within a finite timeframe. Consequently, its scope excluded certain recognized long-term research needs and concentrated on critical shorter term problems. The DMRP was multidisciplinary in every respect and considered a wide range of dredging and disposal situations. Its dynamic planning base allowed it to be modified almost immediately within overall constraints to meet changed priorities arising from evolution of the problems and research results obtained. Its mode of implementation ensured maximum flexibility to pursue the most promising solutions and alternatives while at the same time bringing to bear an immense spectrum of research capability. Perhaps the most important was the well-developed awareness of the need for and steps taken to ensure effective information dissemination and application of results to ongoing projects.

MANAGEMENT. . . . .

The DMRP was managed under a project manager organizational structure within the Environmental Laboratory (EL) (formerly the Environmental Effects Laboratory) of the WES. Project Managers (see Staff section) with technical support staffs were responsible for technical planning, fiscal management, internal and external coordination, technical monitoring of work accomplishment, documentation and reporting, results evaluation and synthesis, and information dissemination and technology transfer. Coordination and overall guidance of the DMRP projects was by an EL Special Assistant who reported directly to the chief of EL. The authority and responsibility for final decisions on all actions taken to meet program objectives were vested in a Program Planning Group (PPG) that consisted of all DMRP senior management personnel and the program coordinators.

In addition to implementation of certain research efforts and contract management, EL technical elements contributed heavily toward the planning and management of all DMRP major field investigations. Personnel of the Environmental Resources and Environmental Engineering Divisions of the EL also contributed heavily toward the summary and synthesis of research results.

THE STAFF. . . . .

The scope and diversity of the DMRP plus normal staff turnover during a 5-year period resulted in a substantial number of personnel involved with program management. All deserve recognition for their accomplishments: those who were on the staff at the termination of the DMRP are specially noted and their names appear in italics.

THE CHIEF, EL

John Harrison, Ph. D., Supv Research Civil Engineer

THE SPECIAL ASSISTANT, DMR

R. T. Saucier, Ph. D., Geographer

THE PROGRAM MANAGER

MAJ F. H. Griffis, Jr., Ph. D., Construction Engineer

THE PROJECTS

ENVIRONMENTAL IMPACTS AND CRITERIA DEVELOPMENT PROJECT

Managers

R. M. Engler, Ph. D., Research Soil Scientist
J. W. Keeley, Ph. D., Research Ecologist

Staff

P. R. Becker, Ph. D., Research Biologist
R. E. Hoeppel, Research Microbiologist
B. W. Holliday, Oceanographer
S. E. Palmer (Harrison), Biologist
R. K. Peddicord, Ph. D., Physical Scientist
R. H. Plumb, Jr., Ph. D., Physical Scientist

HABITAT DEVELOPMENT PROJECT

Managers

C. J. Kirby, Ph. D., Research Ecologist
H. K. Smith, Ph. D., Research Wildlife Biologist

Staff

L. F. Holloway, Ph. D., Research Ecologist
R. T. Huffman, Ph. D., Botanist
L. J. Hunt, Wildlife Biologist
M. C. Landin, Biologist
J. D. Lunz, Marine Biologist
T. R. Patin, Civil Engineer
G. E. Tucker, Ph. D., Research Botanist

DISPOSAL OPERATIONS PROJECT

Managers

C. C. Calhoun, Jr., Research Civil Engineer
R. L. Montgomery, Research Civil Engineer

Staff

N. C. Baker, Research Civil Engineer
W. D. Barnard, Ph. D., Oceanographer
T. A. Haliburton, Ph. D., Geotechnical Engineering Consultant
M. L. Hayden, Civil Engineer
T. K. Moore, Sanitary Engineer
M. E. Poindexter, Civil Engineer
J. W. Spotts, Ph. D., Research Soil Scientist

PRODUCTIVE USES PROJECT

Managers

CPT R. M. Meccia, Civil Engineer (Env)
T. R. Patin, Civil Engineer
R. T. Saucier, Ph. D., Geographer

Staff

M. R. Walsh, Civil Engineer

THE COORDINATORS

K. O. Allen, Ph. D., Fishery Biologist (Fish & Wildlife Service)
CPT W. C. Allanach, Jr., Civil Engineer
MAJ M. D. Malkasian, Civil Engineer
CPT R. M. Meccia, Civil Engineer (Env)

PLANNING CONSULTANT

M. B. Boyd, Supv Research Hydraulic Engineer

MANAGEMENT SUPPORT

Throughout the DMRP, personnel of the Environmental Resources Division of the EL (C. J. Kirby, Ph. D., Chief) and the Environmental Engineering Division (A. J. Green, Chief) provided task planning and especially field site management support to the DMRP. The latter included development and implementation of research designs and rationales, coordination, and interpretation and reporting of results. Particular individuals making significant contributions included:

H. H. Allen, Research Ecologist
M. J. Bartos, Jr., Civil Engineer
P. R. Becker, Ph. D., Research Biologist

C. R. Bingham, Limnologist
C. G. Boone, Oceanographer
J. S. Boyce, Ph. D., Soil Scientist
E. J. Clairain, Fishery Biologist
S. P. Cobb, Marine Biologist
R. A. Cole, Ph. D., Research Ecologist
R. J. Diaz, Ph. D., Research Marine Biologist
P. L. Doiron, Mathematician
M. P. Farrell, Ph. D., Ecological Statistician
A. W. Ford, Electrical Engineer
W. B. Gallagher, Ph. D., Research Biologist
D. A. Goss, Civil Engineer
M. A. Granat, Geologist
L. J. Hunt, Wildlife Biologist
J. H. Johnson, Research Limnologist
J. L. Llopis, Geologist
J. D. Lunz, Marine Biologist
A. D. Magoun, Ph. D., Statistician
D. B. Mathis, Marine Biologist
R. L. Montgomery, Supv Research Civil Engineer
M. R. Palermo, Research Civil Engineer
D. R. Parsons, Ecologist
E. P. Peloquin, Ph. D., Wildlife Biologist
C. H. Pennington, Ph. D., Fisheries Biologist
J. R. Reese, Microbiologist
J. R. Seelye, Ph. D., Limnologist
H. K. Smith, Ph. D., Research Wildlife Biologist
P. A. Spaine, Civil Engineer
J. E. Unsicker, Ph. D., Botanist
M. K. Vincent, Physical Scientist
T. M. Walski, Sanitary Engineer
B. R. Wells, Ph. D., Soil Chemist
T. J. Wood, Ph. D., Supv Research Water Resources Specialist
D. A. Wright, Civil Engineer
T. D. Wright, Ph. D., Research Biologist

In addition, numerous personnel of the Technical Communications Group (D. P. Booth, Chief) and the Management Support Group (J. T. Ransome, Chief) of the EL contributed appreciably to the accomplishment of the DMRP.

FUNDING. . . . .

Total funding for the DMRP amounted to $32,878,000 in yearly increments as follows:

- FY 73 $1,300,000
- FY 74 $3,900,000
- FY 75 $8,200,000
- FY 76 $9,400,000
- FY 7T $2,685,000
- FY 77 $5,493,000
- FY 78 $1,900,000

Total expenditures for research involved 67% of each dollar while the remaining 33% was used for management and related activities (planning, supervision, study management, coordination, consultation, travel, reports preparation and publication, information dissemination, etc.). Being an aspect emphasized throughout the DMRP, technology transfer accounted for a large percentage of the nonresearch part of each dollar.

Referring to the specific goals of the DMRP, distribution of the research dollar involved:

- 40% for studies of the environmental effects of disposal operations
- 30% for testing and evaluating concepts of marsh and wildlife habitat development
- 22% for studies related to improving land disposal as an alternative and regulation of the disposal operation
- 8% for developing and testing concepts of productive uses of dredged material

RESEARCH ACCOMPLISHMENT. . . . .

Approximately one-half of the more than 250 individual studies (work units) in the DMRP were contracted as a result of competitive advertisement of Scopes of Work. Coupled with the funding of about a dozen unsolicited proposals and 18 work units accomplished by other Federal agencies, this resulted in over 60% of the DMRP conducted outside of the Corps. This diversity in regard to the individuals and groups implementing the DMRP, summarized below, was a strong point of the program and hopefully contributed to its quality and credibility.

CATEGORY	NO. OF WORK UNITS	TOTAL COST
In-house (WES) or Corps	102	$ 6,574,900
Contracts with commercial firms	72	5,233,700
Contracts with universities/institutes	77	8,791,700
Other Federal agencies	18	1,413,100
Program Totals	269	$22,013,400

The names of the DMRP contractors and implementing groups, together with the names of the principal investigators, are listed alphabetically in Appendix A. Included are 47 commercial firms, 37 universities or university-affiliated institutes, 12 offices of 6 Federal and 1 State agency, 6 individuals, 3 other Corps Laboratories, 9 Corps Districts, and 10 WES organizational elements.

TECHNICAL STRUCTURE. . . . .

At the beginning, the DMRP was subdivided for planning and management purposes into 26 tasks that represented basic program objectives. As a reflection of the dynamic technical planning provision of the DMRP (implemented via a Program Planning Group), the technical structure was twice reviewed and revised as problems were better defined and priorities changed. By the third year, the final structure emerged, consisting of 20 research-oriented tasks and 1 program-wide task concerned with technology transfer and applications.

To serve as a guide to the second part of this Detailed Summary, the DMRP technical structure is summarized below:

RESEARCH PROJECTS	RESEARCH TASKS
ENVIRONMENTAL IMPACTS AND CRITERIA DEVELOPMENT	1A Aquatic Disposal Field Investigations 1B Movements of Dredged Material 1C Effects of Dredging and Disposal on Water Quality 1D Effects of Dredging and Disposal on Aquatic Organisms 1E Pollution Status of Dredged Material 2D Confined Disposal Area Effluent and Leachate Control
HABITAT DEVELOPMENT	2A Effects of Marsh and Terrestrial Disposal 4A Marsh Development 4B Terrestrial Habitat Development 4E Aquatic Habitat Development 4F Island Habitat Development
DISPOSAL OPERATIONS	2C Containment Area Operations 5A Dredged Material Densification 5C Disposal Area Reuse 6B Treatment of Contaminated Dredged Material 6C Turbidity Prediction and Control
PRODUCTIVE USES	3B Upland Disposal Concepts Development 4C Land Improvement Concepts 4D Products Research 5D Disposal Area Land Use Concepts
	9A Research Results Applications

CONSULTANTS. . . . .

The DMRP made liberal and effective use of consultants at all levels and for a variety of purposes ranging from overall program review and guidance and the planning of entire tasks to the preparation of specific Scopes of Work and the review of reports. Of the more than two dozen scientists and engineers representing academia, industry, government, and research that were retained, the following 8 individuals provided continued critique and advice on program-level progress and plans:

- Richard H. Backus, Ph. D. (Marine Biologist), Woods Hole Oceanographic Institution
- Robert S. Clas (Dredging Consultant), Robert Clas & Associates
- Arthur W. Cooper, Ph. D. (Plant Ecologist), North Carolina State University
- W. Wesley Ekenfelder, Jr. (Sanitary Engineer), Vanderbilt University
- G. Fred Lee, Ph. D. (Environmental Chemist), University of Texas at Dallas
- John Lowe III (Soils Engineer), Tippets-Abbett-McCarthy-Stratton, Inc.
- William H. Patrick, Jr., Ph. D. (Soil/Sediment Chemist), Louisiana State University
- Thomas G. Scott, Ph. D. (Zoologist), U. S. Fish and Wildlife Service

COORDINATION AND TECHNOLOGY TRANSFER. . . . .

The specific functions of coordination for awareness purposes and avoidance of duplication of effort, and the dissemination of information to promote the application of research results were handled concurrently within the DMRP at a priority equal to actual research accomplishment. Nearly all of the numerous efforts in these categories contributed to both and included:

- 2 full-time coordinator staff positions (for both interagency and intra-agency coordination)
- Agreement with the U. S. Fish and Wildlife Service for a full-time coordinator for the DMRP from that agency
- 11 formal Semiannual Interagency Briefings in Washington
- Establishment of a Dredging Industry Coordinating Committee
- Establishment of an EPA/Corps Technical Committee on Criteria Development
- Professional society conference and meeting participation and sponsorship of special sessions
- Membership on boards, committees, panels, etc., at the regional, national, and international levels
- Cooperative projects with 11 Corps Districts and field tests in several others
- 19 Corps Division-area briefings/workshops during a 21-month period

PUBLICATIONS. . . . .

The DMRP was a prolific producer of reports and other publications, both in terms of number of separate items and number of copies printed. The more significant of these consisted of:

- 55 Information Exchange Bulletins
- 24 Miscellaneous Papers
- 174 Contract and Technical Reports
- 21 Synthesis Reports
- 4 Annual Reports
- 1 Public Information Brochure
- 1 Publication Index and Retrieval System

Designed to disseminate information rapidly in condensed form to a large audience, the Information Exchange Bulletins were distributed free of charge to over 3000 recipients. Copies of certain more recent editions may still be available upon request.

The Contract and Technical Reports generally were out of print within 6 months of publication. However, complete sets are available in all Corps District and Division offices and numerous other Federal agencies. All reports are available for purchase in unlimited numbers in either microfiche or hard copy from the National Technical Information Service (NTIS), Springfield, VA 22151.

Synthesis Reports were published in larger quantities to meet a higher demand and are available individually or in sets free of charge as long as copies remain. They also will be available indefinitely through the NTIS. The Synthesis Reports represent the primary means of condensation of the large volume of technical data and serve as the summary documents emphasizing the significance and application of research results.

PUBLICATION INDEX AND RETRIEVAL SYSTEM. . . . .

All DMRP Miscellaneous Papers, Contract and Technical Reports, and Synthesis Reports are referenced with full citations under the appropriate tasks in this summary report. This will provide ready access to all published information available from the DMRP on a given major subject area or program objective.

However, on the basis of titles alone, it may be difficult for a reader to locate or retrieve specific information. To accommodate this need and to provide information access to the numerous users who are not aware of this report or the technical structure of the DMRP, a comprehensive index and retrieval system is available as Technical Report DS-78-23. Prepared under contract by a firm of information specialists, this report contains multiple informative abstracts for each DMRP report and title, author, subject, and geographical area indexing.

RELATED ACTIVITIES. . . . .

Throughout the DMRP, appreciable attention and effort were devoted to promoting the prompt and effective application of research results being obtained to efforts related to regulatory program planning and initiation. Publication in the *Federal Register* (Vol. 42, No. 7, Tuesday, 11 January 1977) of the final ocean dumping guidelines pursuant to Public Law 92-532 was the stimulus that led to specific application of DMRP research results in the publication of a joint Corps/EPA implementation manual for the regulatory program. The specific report involved is:

> EPA/CE Technical Committee on Criteria for Dredged and Fill Material, "Ecological Evaluation of Proposed Discharge of Dredged Material into Ocean Waters; Implementation Manual for Section 103 of Public Law 92-532 (Marine Protection, Research, and Sanctuaries Act of 1972)," July 1977, published by the Environmental Effects Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

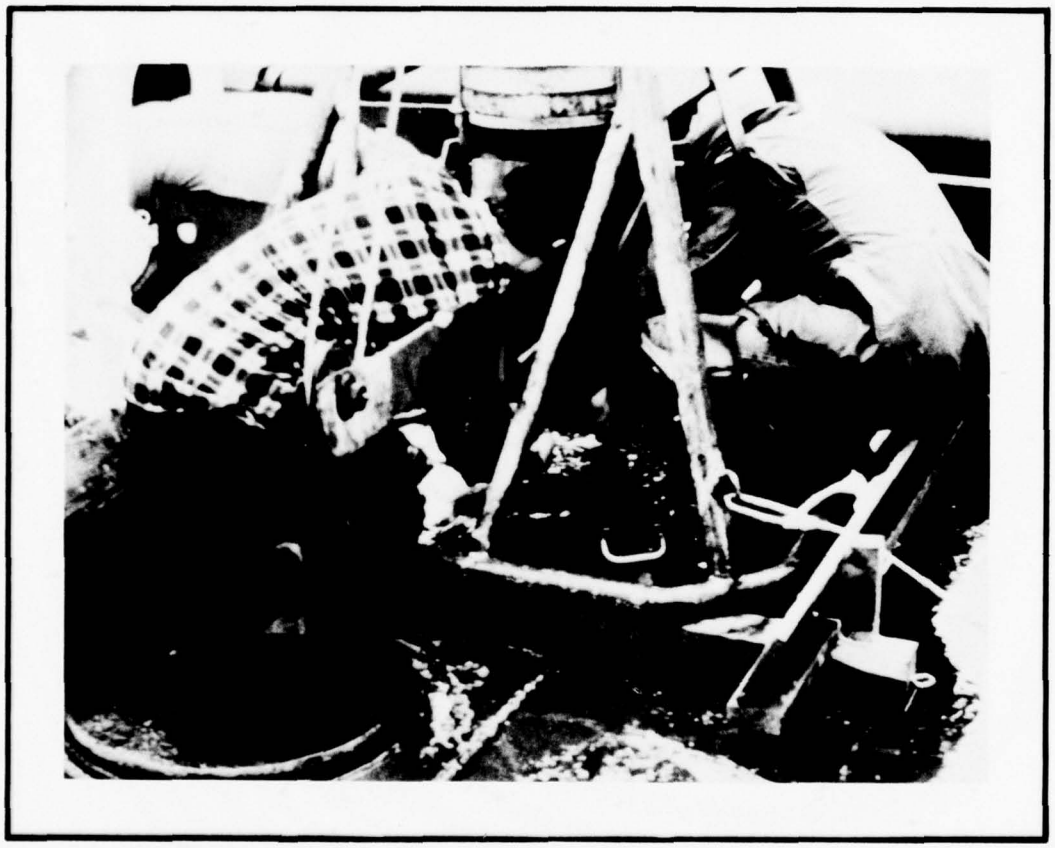
Coordination of DMRP research relevant to the disposal of dredged or fill material in both oceanic and inland waters (Public Laws 92-532 and 92-500) with that being done elsewhere within the Corps and the Environmental Protection Agency (EPA) was effected beginning in 1975 via the EPA/CE Technical Committee on Criteria for Dredged and Fill Material. In addition to research coordination, substantial contributions were made to two other committee objectives, i.e., providing technical guidance for criteria revision and refinement and for development of implementation manuals. Special emphasis has been placed on development of wetlands vegetation identification guidelines and coordination with EPA and Fish and Wildlife Service activities in wetlands.

Specific research activities within the DMRP applicable to technical criteria and guidelines development are largely included under Task 1E: Pollution Status of Dredged Material. Supplemental work was accomplished and will continue for several more years under separate sponsorship of the Office, Chief of Engineers. Several publications will result and will be published by the Environmental Laboratory of WES.

Research Tasks

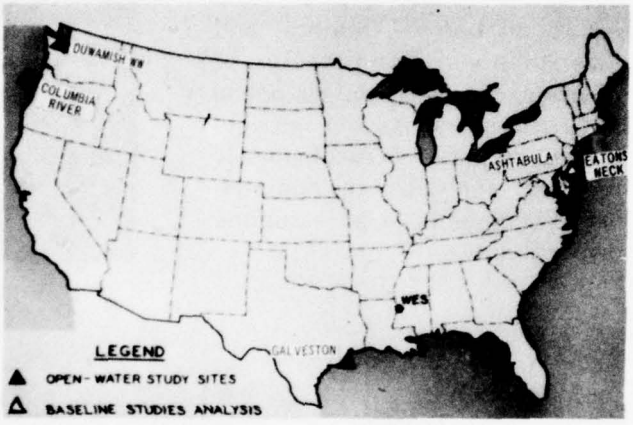
AQUATIC DISPOSAL FIELD INVESTIGATIONS

(Task 1A: Environmental Impacts and Criteria Development Project)



OBJECTIVE. . . . .

—to determine the magnitude and extent of effects of disposal sites on organisms and the quality of surrounding water, and the rate, diversity, and extent such sites are recolonized by benthic flora and fauna—



APPROACH. . . . .

—select active sites representative of different regions and disposal plans; conduct monitored, controlled disposal operations and compare results to baseline conditions and reference sites; evaluate results in terms of hypotheses and lab study findings of other tasks—

IMPLEMENTATION. . . . .

—30 total work units (6 in-house efforts, 17 contracts, 7 interagency agreements), involving a total expenditure of $4,697,894.

—bulk of effort (20 work units) expended at 5 major field sites.

—all field site study results presented in 5 site reports; other final results presented in 29 additional in-house and contractor-prepared technical reports and 1 Synthesis Report.

THE FIELD SITES. . . . .

EATONS NECK (New York):

Objective and Approach—

—through before-, during-, and after-disposal monitoring of physical, chemical, and biological parameters, assess the impacts of the disposal of mechanically dredged, fine-grained, contaminated sediments at an estuarine disposal site—

Results—

SHORT-TERM IMPACTS. No acute effects could be assessed since the study was terminated prior to the scheduled disposal operation because of local opposition to disposal-related research in Long Island Sound.

LONG-TERM IMPACTS. Baseline studies at the site failed to reveal any significant cumulative impacts of the historic disposal activities other then a change in bottom geometry. From a biological point of view, this change may have been instrumental in enhancing the lobster fishery of the area.

Work Units—

1A06A An Investigation of the Hydraulic Regime, the Meteorology, and the Physical Nature of Bottom Sedimentation in the Eatons Neck Disposal Site. Yale University. $145,390. Report published as Appendix A to site report (TR D-77-6).

1A06B An Investigation of the Water-Quality Parameters and the Physicochemical Sediment Parameters at the Eatons Neck Disposal Site. State University of New York at Stony Brook. $284,115. Report published as Appendix B to site report (TR D-77-6).

1A06C Baseline Studies of Plankton, Nekton, and Benthic Invertebrate Populations of the Eatons Neck Disposal Site. New York Ocean Science Lab. $264,717. Report published as Appendixes C, D, E, and F to site report (TR D-77-6).

COLUMBIA RIVER (Oregon):

Objective and Approach—

—evaluate the acute and long-term effects of on-shelf oceanic hopper dredge disposal of coarse-grained dredged material at a regionally representative disposal site off the mouth of the Columbia River—

Results—

SHORT-TERM IMPACTS. Chemical analyses of the water column suggest that there were no discernible effects associated with the discharge of approximately 600,000 cubic yards of dredged material. Acute biochemical effects were insignificant and intermediate-term chemical mobilization from the dump site was not detected. Physical mounding of the material was evident at this site.

LONG-TERM IMPACTS. Biological investigations suggest slow recolonization (1 to 3 years to biological stability) of the coarse-grained material by organisms native to the area. No biochemical/contaminant impacts were noted at this site. Long-term water column and benthic biota investigation reports are being prepared at this time; consequently, final interpretation of results is not available.

Work Units—

1A07A An Investigation of the Hydraulic Regime, the Meteorology, and the Physical Nature of Bottom Sedimentation in the Columbia River Disposal Site. University of Washington. $286,262. Report published as Appendix A to site report (TR D-77-30).

1A07B An Investigation of the Water-Quality Parameters and the Physicochemical Sediment Parameters at the Columbia River Disposal Site. Oregon State University. $264,890. Report published as Appendix B to site report (TR D-77-30).

1A07C Baseline Studies of Benthic Invertebrate Populations at the Columbia River Disposal Site. Oregon State University. $251,412. Report published as Appendix C to site report (TR D-77-30).

1A07D Baseline Studies of Plankton Population at the Columbia River Disposal Site. Oregon State University. $94,135. Report published as Appendix D to site report (TR D-77-30).

1A07E Baseline Studies of Fisheries at the Columbia River Disposal Site. Northwest Fisheries Center, National Marine Fisheries Service, NOAA. $114,522. Report published as Appendix E to site report (TR D-77-30).

1A07F Assistance of Portland District Personnel for the Oregon State University Research Team. Portland District. $8,000. No report published.

LAKE ERIE (Ashtabula, Ohio):

Objectives and Results—

—to contrast spring and summer hopper dredge disposal of contaminated harbor sediment on a freshwater aquatic system; ascertain the long-term biochemical impact at a historical dump site in Lake Erie off Ashtabula Harbor, Ohio—

Results—

SHORT-TERM IMPACTS. Release to the water column of orthophosphate, ammonium, and reactive silica occurred at disposal. The water column returned to ambient conditions within a few hours. No metals or hydrocarbons were released and only a small level of suspended particulates could be detected. No impacts on the plankton community were noted. Fish were neither attracted to nor avoided the dumping operation. Physical mounding at the site was evident.

LONG-TERM IMPACTS. The disposal mound has significantly decreased in size, suggesting sediment consolidation and erosion. However, the magnitude of sediment resuspension-transport is not known. The benthic fauna were impacted during disposal; however, recolonization was rapid. Release of contaminants from the disposal mound was not detected. Recolonization of the site occurred rapidly and there was no evidence of bio-accumulation of contaminants within the benthos as a consequence of disposal.

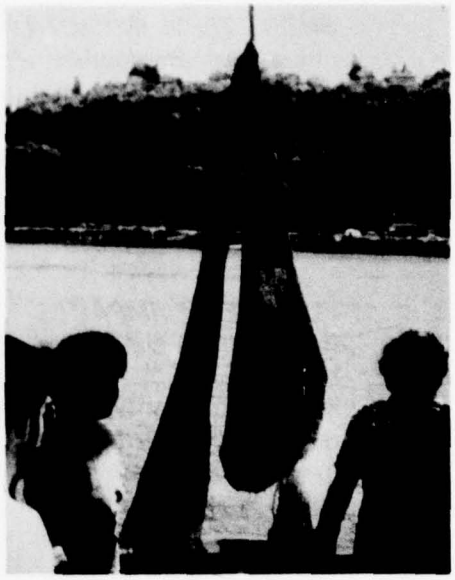
Work Units—

1A08A, 1A08C — An Investigation of Planktonic Communities, Benthic Assemblages, and the Fishery Associated with the Ashtabula Harbor Disposal Sites; and An Investigation of the Water-Quality Parameters and the Physicochemical Sediment Parameters in the Ashtabula Harbor Disposal Site. Great Lakes Laboratory, State University of New York at Buffalo. $641,938. Reports published as Appendixes A and C to site report (TR D-77-42).

1A08B — An Investigation of the Hydraulic Regime and the Physical Nature of Bottom Sedimentation Associated with the Ashtabula Harbor Disposal Site. NALCO Environmental Sciences. $281,539. Report published as Appendix B to site report (TR D-77-42).

GULF OF MEXICO (Galveston, Texas):

Objectives and Approach—



—investigate impacts of open Gulf discharge of hopper dredged noncontaminated fine-grained and coarse-grained material from the Galveston Bay entrance channel bar and highly contaminated sediments from the Texas City ship channel; emphasis placed on acute impacts from the fine-grained material and benthic recolonization of the dump site—

Results—

SHORT-TERM IMPACTS. Water column impacts were short lived. Ammonium and manganese were released from the contaminated material and remained for less than a few hours. Summer disposal caused no apparent change in the infaunal species composition or relative abundance at the dump site. Late winter-early spring disposals are still being evaluated.

LONG-TERM IMPACTS. Due to a rapidly changing hydrodynamic regime, the bottom geometry of the dump site is continuously changing, leaving only the coarsest grained material and some clay that is resistant to erosion. There were no identifiable impacts on the benthic community of the dump site when contrasted to reference areas.

Work Units—

1A09A An Investigation of the Hydraulic Regime and Physical Nature of Sedimentation at the Galveston Disposal Site. Texas A&M Research Foundation. $178,752. Report published as Appendix A to site report (TR D-77-20).

1A09B An Investigation of the Biota at the Galveston Disposal Site. Moody College of Marine Sciences and Maritime Resources, Texas A&M University. $169,507. Report published as Appendix C to site report (TR D-77-20).

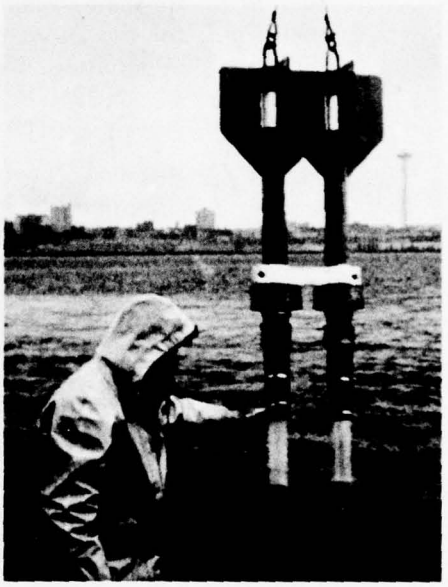
1A09C An Investigation of the Water-Quality Parameters and Physicochemical Parameters at the Galveston Disposal Site. University of Texas at Dallas. $176,220. Report published as Appendix B to site report (TR D-77-20).

1A09D Assistance of Galveston District. Galveston District. $26,226. No report published.

DUWAMISH WATERWAY (Puget Sound, Washington):

Objectives and Approach—

—to investigate the disposal in an estuarine location of fine-grained sediments contaminated with PCB's, metals, and petroleum hydrocarbons. The sediments were dredged mechanically and barged to an Elliott Bay, Puget Sound, site with a depth of 200 feet—



Results—

SHORT-TERM IMPACTS. Suspended sediment impacts on the water column were of short duration (2 hours) and occurred near the bottom. Dissolved oxygen reductions were less than 1 part per million and lasted less than 30 minutes. Metals were not detected in the water column in dissolved form. PCB's were released at a few parts per trillion and were detected for only a few minutes. Ammonium was released in small quantities for a few minutes. Benthic organism density and biomass were significantly impacted at the time of discharge.

LONG-TERM IMPACTS. Benthic recolonization by a wide range of organisms occurred rapidly (3 to 6 months to return to original biomass) over all areas of the impacted site. There was no elevated uptake of metals or PCB's in crustaceans, bivalves, or flatfish collected on the dump site several months after disposal. Other than the physical impact of the mound at the dump site, impacts of the disposal appear minimal.

Work Units—

1A10A Pilot Survey—Selection of Research Area. National Marine Fisheries Service, NOAA. $23,954. No final report published.

1A10B Baseline, Disposal, and Postdisposal Biological Studies for the Duwamish Waterway Aquatic Disposal Field Investigation. National Marine Fisheries Service, NOAA. $202,336. Published as Appendixes A, B, C, F, and G to site report (TR D-77-24).

1A10C Baseline, Disposal, and Postdisposal Sediment and Water Chemistry Studies for the Duwamish Waterway Aquatic Disposal Field Investigation. EPA. $299,844. Published as Appendix D (Vol I) to site report (TR D-77-24).

1A10D Continuation of the Sediment and Water Physicochemical Studies Associated with the Disposal Operation of Duwamish River Sediments in Elliott Bay, Puget Sound, Washington. University of Washington. $114,042. Published as Appendixes D (Vol II) and E to site report (TR D-77-24).

FIELD STUDY SUPPORT EFFORTS. . . . .

1A01 Collection and Assessment of Data on Open-Water Disposal Sites. Interlaboratory Team, WES. $124,785. Results incorporated into Internal Working Document.

OTHER TASK 1A WORK UNITS. . . . .

1A11 An Assessment of the Potential Impact of Dredged Material Disposal in the Open Ocean. TerEco. $80,190. Report published as TR D-78-2.

3A01 Investigation of Subaqueous Borrow Pits as Potential Sites for Dredged Material Disposal. Soils and Pavements Laboratory (S&PL), WES. $57,400. Report published as TR D-77-5.

3A02 State-of-the-Art Survey and Evaluation of Open-Water Dredged Material Placement Methodology. JBF Scientific Corporation. $70,421. Report published as CR D-76-3.

1A02 Determination of Benthic Colonization Control Factors, EL, WES. $18,673. Data input to 1A05.

1A03 Monitoring Equipment, Methodology, and Institutional Capabilities Survey. Mobility and Environmental Systems Laboratory (MESL), WES. $58,324. Results incorporated into Internal Working Document.

1A03A A Nationwide Calibration, Standardization, and Evaluation of Environmental Monitoring Instrumentation for the Aquatic Disposal Research Project. National Oceanographic Instrumentation Center, NOAA. $95,000. No final report published.

1A04 Development and Implementation of Information Storage and Retrieval System, EL and Concrete Laboratory (CL), WES. $291,410. No final report published. User manual available.

1A05 Selection of Test Sites and Design of Field Studies, Open-Water Dredged Material Disposal Sites. Interlaboratory Team, WES. $63,890. Report published as MP D-75-13.

1A12 Aquatic Disposal Field Investigations—A Synthesis Report. T. D. Wright. $10,000. Report published as TR DS-78-1.

REPORTS PUBLISHED. . . . .

MP D-75-13 (Work Unit 1A05)	Becker, P. R., Holliday, B. W., Palmer, S. E., and Engler, R. M., "General Research Plan for the Field Investigations of Coastal Dredged Material Disposal Areas," April 1975, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A009 523.
CR D-76-3 (Work Unit 3A02)	Johanson, E. E., Bowen, S. P., and George, H., "State-of-the-Art Survey and Evaluation of Open-Water Dredged Material Placement Methodology," April 1976, prepared by JBF Scientific Corporation, Burlington, Massachusetts, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A027 024.
TR D-77-5 (Work Unit 3A01)	Broughton, J. D., "Investigation of Subaqueous Borrow Pits as Potential Sites for Dredged Material Disposal," May 1977, Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A043 052.
TR D-77-6	Aquatic Disposal Field Investigations, Eatons Neck Disposal Site, Long Island Sound.
Site Report (Work Unit 1A06)	Cobb, S. P., et al., "An Environmental Inventory," May 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A 055 217.
Appendix A (Work Unit 1A06A)	Bokuniewicz, H. J., et al., "Investigation of the Hydraulic Regime and the Physical Characteristics of Bottom Sedimentation," August 1977, prepared by the Department of Geology and Geophysics, Yale University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A047 421.
Appendix B (Work Unit 1A06B)	Marine Sciences Research Center, "Water-Quality Parameters and Physicochemical Sediment Parameters," January 1978, prepared by State University of New York under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A053 427.

Appendix C (Work Unit 1A06C)	Serafy, D. K., et al., "Predisposal Baseline Conditions of Benthic Assemblages," November 1977, prepared by New York Ocean Science Laboratory under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 046.
Appendix D (Work Unit 1A06C)	Valenti, R. J., and Peters, S., "Predisposal Baseline Conditions of Demersal Fish Asssemblages," August 1977, prepared by New York Ocean Science Laboratory under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A045 720.
Appendix E (Work Unit 1A06C)	Caplan, R. I., "Predisposal Baseline Conditions of Zooplankton Assemblages," August 1977, prepared by the New York Ocean Science Laboratory under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A045 310.
Appendix F (Work Unit 1A06C)	Nuzzi, R., "Predisposal Baseline Conditions of Phytoplankton Assemblages," August 1977, prepared by the New York Ocean Science Laboratory under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A045 313.
TR D-77-20	Aquatic Disposal Field Investigations, Galveston, Texas, Offshore Disposal Site.
Site Report (Work Unit 1A09)	Wright, T. D., et al., "Evaluative Summary," May 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 812.
Appendix A (Work Unit 1A09A)	Estes, E. L., et al., "Investigation of the Hydraulic Regime and Physical Nature of Sedimentation," December 1977, prepared by Texas A&M University under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 812.
Appendix B (Work Unit 1A09C)	Lee, G. F., et al., "Investigation of Water-Quality Parameters and Physicochemical Parameters," December 1977, prepared by the Center of Environmental Studies, University of Texas at Dallas, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A053 102.

Appendix C (Work Unit 1A09B)	Harper, D. E., "Investigation of the Effects of Dredging and Dredged Material Disposal on the Offshore Biota," May 1978, prepared by Texas A&M University under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report. NTIS No. AD A061 844.
TR D-77-24	Aquatic Disposal Field Investigations, Duwamish Waterway Disposal Site, Puget Sound, Washington.
Site Report (Work Unit 1A10)	Tatem, H. E., and Johnson, J. H., "Evaluative Summary," June 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 445.
Appendix A (Work Unit 1A10B)	Hughes, J. R., et al., "Effects of Dredged Material Disposal on Demersal Fish and Shellfish in Elliott Bay, Seattle, Washington," May 1978, prepared by the National Marine Fisheries Service under contract to the U.S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 268.
Appendix B (Work Unit 1A10B)	Stout, V. F., and Lewis, L. G., "Role of Disposal of PCB-Contaminated Sediment in the Accumulation of PCB's by Marine Animals," November 1977, prepared by Northwest and Alaska Fisheries Center under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A055 218.
Appendix C (Work Unit 1A10B)	Teeny, F. M., and Hall, A. S., "Effects of Dredged Material Disposal on the Concentration of Mercury and Chromium in Several Species of Marine Animals," November 1977, prepared by the National Marine Fisheries Service under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A049 616.
Appendix D (Work Unit 1A10C)	Baumgartner, D. J., et al., "Chemical and Physical Analyses of Water and Sediment in Relation to Disposal of Dredged Material in Elliott Bay; Volume I: February-June 1976," June 1978, prepared by the Corvallis Environmental Research Laboratory, Environmental Protection Agency, under interagency agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 000.

(Work Unit 1A10D) Sugai, S., et al., "Chemical and Physical Analyses of Water and Sediment in Relation to Disposal of Dredged Material in Elliott Bay; Volume II: September-December 1976," June 1978, prepared by the College of Fisheries, University of Washington at Seattle, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 001.

Appendix E (Work Unit 1A10D) Pavlou, S. P., et al., "Release and Distribution of Polychlorinated Biphenyls Induced by Open-Water Dredge Disposal Activities," January 1978, prepared by the Department of Oceanography, University of Washington, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 987.

Appendix F (Work Unit 1A10B) Harman, R. A., and Serwold, J. C., "Recolonization of Benthic Macrofauna over a Deep-Water Disposal Site," June 1978, prepared by Shoreline Community College, Seattle, Washington, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.

Appendix G (Work Unit 1A10B) Bingham, C. R., "Benthic Community Structural Changes Resulting from Dredged Material Disposal, Elliott Bay Disposal Site," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 950.

TR D-77-30 Aquatic Disposal Field Investigations, Columbia River Disposal Site, Oregon.

Site Report (Work Unit 1A07) Boone, C. G., et al., "Evaluative Summary," May 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 925.

Appendix A (Work Unit 1A07A) Sternberg, R. W., et al., "Investigation of the Hydraulic Regime and Physical Nature of Bottom Sedimentation," December 1977, prepared by the Department of Oceanography, University of Washington, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A054 725.

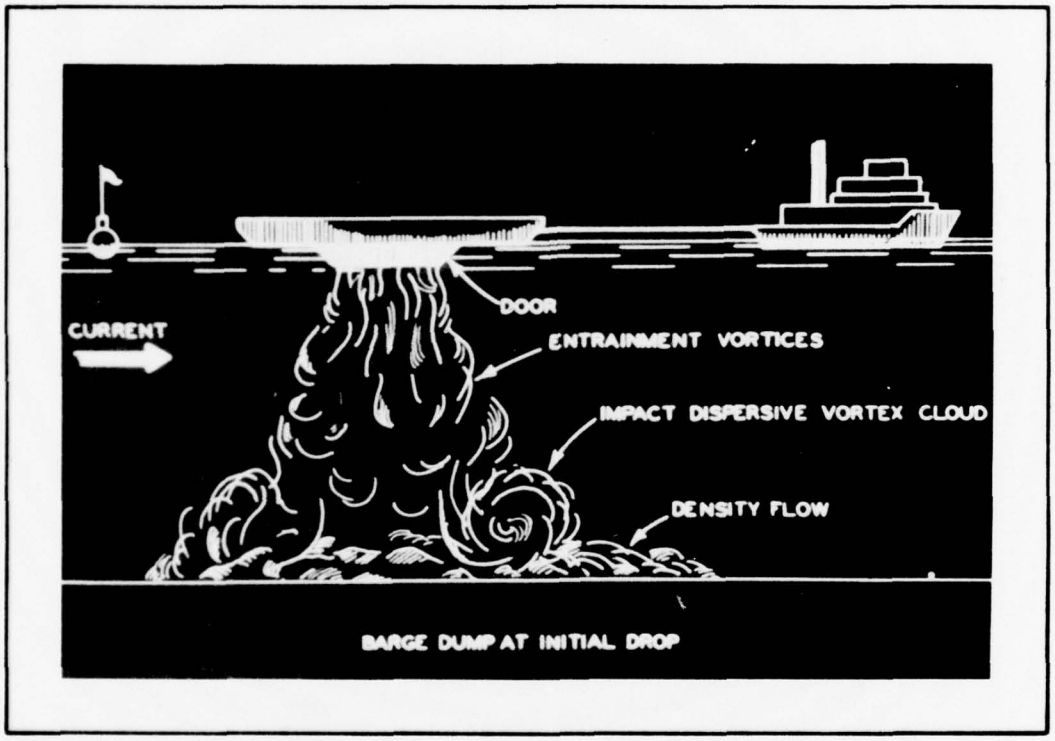
Appendix B (Work Unit 1A07B)	Holton, R. L., et al., "Water Column, Primary Productivity, and Sediment Studies," June 1978, prepared by the School of Oceanography, Oregon State University at Corvallis, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 433.
Appendix C (Work Unit 1A07C)	Richardson, M. D., et al., "The Effects of Dredged Material Disposal on Benthic Assemblages," December 1977, prepared by the School of Oceanography, Oregon State University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A054 561.
Appendix D (Work Unit 1A07D)	Holton, R. L., and Small, L. F., "Zooplankton and Ichthyoplankton Studies," May 1978, prepared by the School of Oceanography, Oregan State University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report. NTIS No. AD A058 433.
Appendix E (Work Unit 1A07E)	Durkin, J. T., and Lipovsky, S. J., "Demersal Fish and Decapod Shellfish Studies," November 1977, prepared by the National Marine Fisheries Service under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A048 412.
TR D-77-42	Aquatic Disposal Field Investigations, Ashtabula River Disposal Site, Ohio.
Site Report (Work Unit 1A08)	Sweeney, R. A., "Evaluative Summary," June 1978, prepared by the Great Lakes Laboratory, State University College at Buffalo, New York, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A055 865.
Appendix A (Work Unit 1A08A)	Sweeney, R. A., "Planktonic Communities, Benthic Assemblages, and Fishery," July 1978, prepared by Great Lakes Laboratory, State University College at Buffalo, New York, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 317.

Appendix B **(Work Unit 1A08B)**	Danek, L. J., et al., "Investigation of the Hydraulic Regime and Physical Nature of Bottom Sedimentation," December 1977, prepared by NALCO Environmental Sciences, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A051 217.
Appendix C **(Work Unit 1A08C)**	Wyeth, R. K., and Sweeney, R. A., "Investigation of Water-Quality and Sediment Parameters," July 1978, prepared by the Great Lakes Laboratory, State University College at Buffalo, New York, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A057 461.
TR D-78-2 **(Work Unit 1A11)**	Pequegnat, W. E., in collaboration with David D. Smith, et al., "An Assessment of the Potential Impact of Dredged Material Disposal in the Open Ocean," January 1978, prepared by TerEco Corporation under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 914.
TR DS-78-1* **(Work Unit 1A12)**	*Wright, T. D., "Aquatic Dredged Material Disposal Impacts," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A060 250.*

* DS in alphanumeric report identification denotes Synthesis Report.

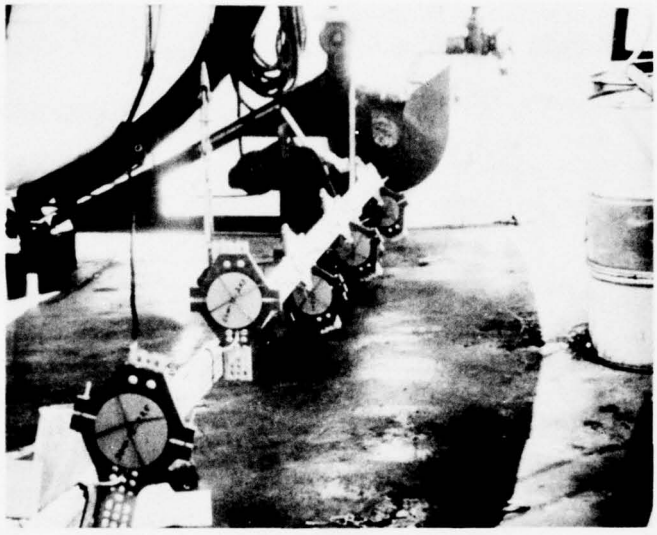
MOVEMENTS OF DREDGED MATERIAL

(Task 1B: Environmental Impacts & Criteria Development Project)



OBJECTIVE. . . . .

—to develop techniques for predicting the spatial and temporal distribution of dredged material discharged into various hydrologic regimes—



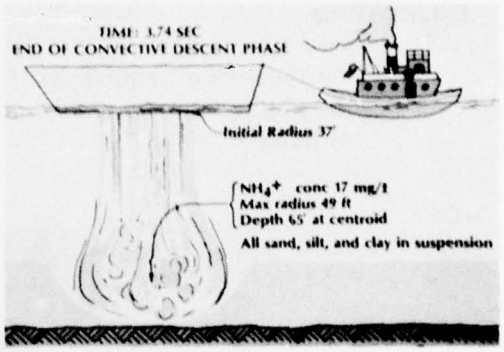
APPROACH. . . . .

—conduct a thorough evaluation of the current state-of-the-art of numerical models for use in predicting sediment dispersion and transport associated with aquatic discharge of dredged material; select or develop appropriate models or concepts; initiate various sensitivity analyses and field verifications requisite to having a predictive tool for the broadest range of conditions and geographical locations—

IMPLEMENTATION. . . . .

—11 total work units (6 in-house efforts, 5 contracts) involving total expenditure of $709,908.
—final results published in 7 in-house and contractor-prepared technical reports and 2 Synthesis Reports.

RESULTS. . . . .



Review—

A review and evaluation of existing models for adaptation to dredged material has shown the Koh-Chang model to have the most promise. There was no model available that could be used for prediction of long-term sediment transport from the discharge site. (See Technical Report D-74-1 and Contract Report D-74-8.)

Development—

The Koh-Chang dispersion model developed by EPA for the ocean disposal of barged wastes was selected and significantly modified for prediction of the dispersion of dredged material in ocean, estuarine, lacustrine, or riverine environments. Development of a two-dimensional sediment transport model for the long-term and ultimate fate of these deposits was initiated. (See Contract Report D-76-5 and Work Unit 1B05.)

Field Verification—

Field verification of the short-term dispersion model was completed and has demonstrated three steps in the aquatic discharge of dredged material: (a) convective descent, (b) dynamic collapse, and (c) long-term release. There was little release of solid material to the water column, and water depth had little effect during descent for hopper and barge disposal. The quantity being discharged had little effect on bottom placement. A general conclusion was that the three-step process allows

for accurate deposition under a range of conditions. Field verification has further demonstrated the usefulness of the model for predicting dispersion from hopper and scow or barge dumps. No field verification is planned for the long-term sediment transport model. (See Technical Report D-78-7 and Work Unit 1B07.)

WORK UNITS. . . . .

1B01	Investigation of Mathematical Models for Predicting the Physical Fate of Dredged Material. Hydraulics Laboratory (HL), WES. $28,400. Report published as TR D-74-1.
1B02	Development of Model for Prediction of Short-Term Fate of Dredged Material Discharged in the Estuarine Environment. Tetra Tech, Inc. $98,310. Report published as CR D-76-5.
1B03	Koh-Chang Model on WES Computer and Survey of Disposal Sites to Determine Applicability of Model. HL, WES. $14,100. June 1974. No final report published.
1B04	Assessment of Factors Controlling the Long-Term Fate of Subaqueous Banks of Dredged Material. Texas A&M Research Foundation. $26,777. Report published as CR D-74-8.
1B05	Development of a Two-Dimensional Sediment Transport Model. University of California at Davis. $120,719. Report published as TR D-77-12.
1B06	Evaluation of Koh-Chang Model (Phase I) and Sensitivity Analyses. HL, WES, and EPA. $20,730. Report published as TR D-78-47.
1B07	Participation in Field Verification of Koh-Chang Model and Further Sensitivity Analysis. HL, WES. $62,000.
1B08	A Field Investigation of the Effects of Winter Storms on the Stability and Fate of Dredged Material in Subaqueous Disposal Areas. Yale University. $6,275. Report published as TR D-77-22.
1B09	An Investigation of the Physical Characteristics of Dredged Material and the Effects of Dispersion Behavior During Open-Water Disposal Operations. Yale University. $242,942. Report published as TR D-78-7.
1B10	Implementation, Evaluation and Documentation of Estuarine Sediment Transport Models and Planning for Field Verification. HL, WES. $65,000. No final report published.

1B11 Fate of Dredged Material Deposits—A Synthesis Report. EL, WES. $24,655. Report published as TR DS-78-2.

1B12 Mathematic Models for Predicting the Fate of Aquatic Disposed Dredged Material—A Synthesis Report. EL and HL, WES. Report published as TR DS-78-3.

REPORTS PUBLISHED. . . . .

TR D-74-1 (Work Unit 1B01) Johnson, B. H., "Investigation of Mathematical Models for the Physical Fate Prediction of Dredged Material," March 1974, Hydraulics Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD 776 368.

CR D-74-8 (Work Unit 1B04) Basco, D. R., Bouma, A. H., and Dunlap, W. A., "Assessment of the Factors Controlling the Long-Term Fate of Dredged Material Deposited in Unconfined Subaqueous Disposal Areas," December 1974, prepared by Texas A&M University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A009 127.

CR D-76-5 (Work Unit 1B02) Brandsma, M. G., and Divoky, D. J., "Development of Models for Prediction of Short-Term Fate of Dredged Material in th Estuarine Environment," May 1976, prepared by Tetra Tech, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A027 131.

TR D-77-12 (Work Unit 1B05) Ariathurai, R., MacArthur, R. C., and Krone, R. B., "Mathematical Model of Estuarine Sediment Transport," October 1977, prepared by the Department of Civil Engineering, University of California at Davis, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A047 202.

TR D-77-22
(Work Unit 1B08)
Bokuniewicz, H. J., et al., "Field Study of the Effects of Storms on the Stability and Fate of Dredged Material in Subaqueous Disposal Areas," prepared by the Department of Geology and Geophysics, Yale University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicskburg, Mississippi. NTIS No. AD A049 978.

TR D-78-7
(Work Unit 1B09)
Bokuniewicz, H. J., et al., "Field Study of the Mechanics of the Placement of Dredged Material at Open-Water Disposal Sites; Volume I: Main Text and Appendixes A-I; Volume II: Appendixes J-O," April 1978, prepared by the Department of Geology and Geophysics, Yale University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS Nos. AD A055 647 and AD A055 648 for Volumes I and II, respectively.

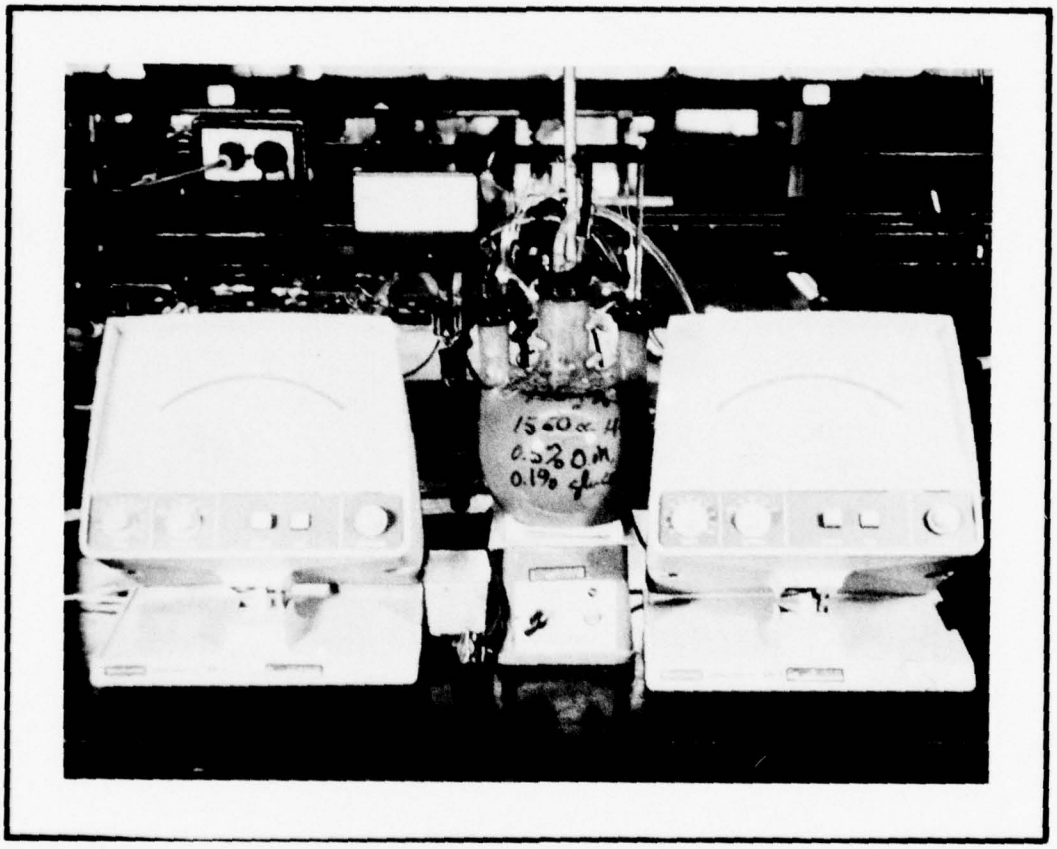
TR D-78-47
(Work Units 1B06 and 1B07)
Johnson, B. H., and Holliday, B. W., "Evaluation and Calibration of the Tetra Tech Dredged Material Disposal Models Based on Field Data," August 1978, Hydraulics Laboratory and Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A060 250.

TR DS-78-2
(Work Unit 1B11)
Holliday, B. W., "Processes Affecting the Fate of Dredged Material," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 276.

TR DS-78-3
(Work Unit 1B12)
Holliday, B. W., Johnson, B. H., and Thomas, W. A., "Predicting and Monitoring Dredged Material Movement," December 1978, Environmental Laboratory and Hydraulics Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 878.

EFFECTS OF DREDGING AND DISPOSAL ON WATER QUALITY

(Task 1C: Environmental Impacts and Criteria Development Project)

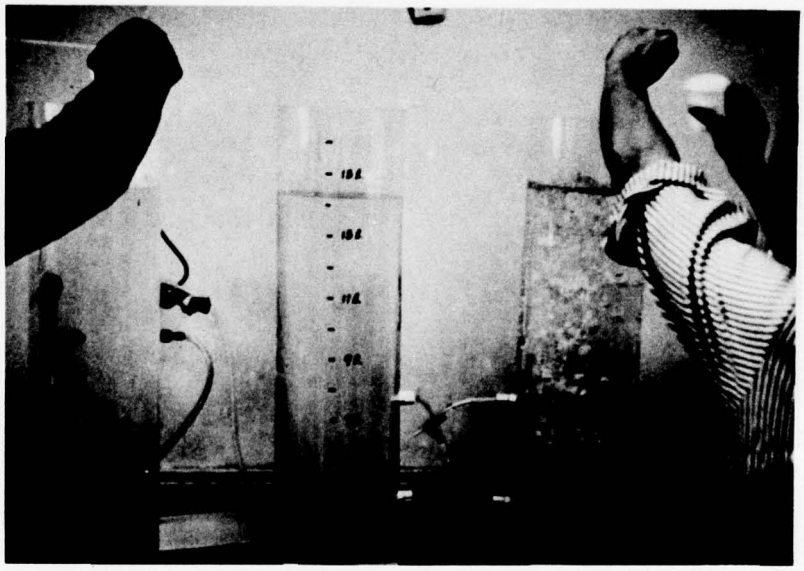


OBJECTIVE. . . . .

—determine through laboratory investigations the short- and long-term effects on water quality due to dredging and discharging bottom sediments containing contaminants—

APPROACH. . . . .

—determine through laboratory simulations the increased or decreased mobility of nutrients, heavy metals, and chlorinated and petroleum hydrocarbons from the sediment to the water column during discharge or from the resettled sediment; evaluate those sediment geochemical and physicochemical parameters that affect contaminant mobility under a broad range of field simulations; determine through range-finding studies those critical parameters that must be investigated in multielement field studies—



STATUS. . . . .

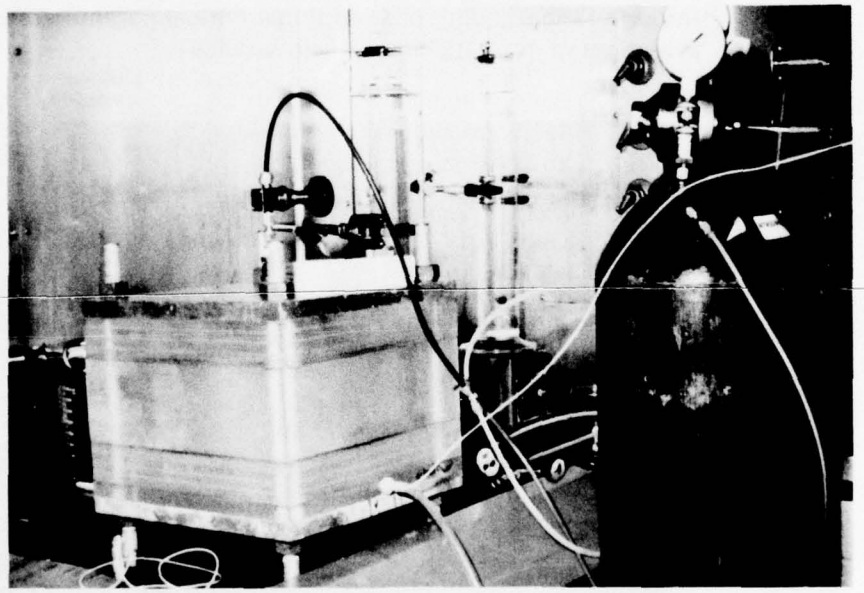
—6 work units (2 in-house efforts, 4 contracts) involving a total expenditure of $421,772.

—final results published in 4 contractor-prepared technical reports and 1 Synthesis Report.

RESULTS. . . . .

Water Column Impacts, Descent Phase—

Constituents released to the water column from a broad range of sediments tested were ammonium, orthophosphate, manganese, iron, and suspended particulates. Ammonium was released in levels that could be considered toxic in areas of poor mixing. There was no release of other metals and nutrients, chlorinated hydrocarbons, and petroleum hydrocarbons in the dissolved state to the water column. It was found, however, that the sediments scavenged the water column of numerous constituents when fine-grained harbor sediments were dispersed in a water column. (See Contract Reports D-75-6, D-76-1, and D-76-7.)



Long-Term Release—

Inorganic constituents released from the settled sediments to the water column (with the exception of iron, manganese, and nutrients) were in extremely small amounts (sub parts per billion) from either contaminated or noncontaminated sediments. The mobilization processes and transformations appear to occur naturally in all fine-grained sediments at similar levels and do not appear to be a significant factor in pollution. Chlorinated and petroleum hydrocarbons apparently were not released from the resettled sediments. (See Contract Reports D-75-6, D-76-1, and D-76-7.)

Controlled Environment –

Sediment/water systems were kept under physicochemical controls that simulated aquatic discharge, upland or contained disposal, and marsh (intertidal) situations. Mobilization was significantly enhanced or retarded when the physicochemical environment was changed. Maximum release was noted under acid/oxidizing conditions; however, these conditions do not normally occur in an open-water disposal or intertidal situation. They could occur in upland contained or noncontained terrestrial sites. Consequently, judicious selection of the disposal mode (open water versus upland) and an understanding of the long-term implications of either disposal mode are imperative. (See Contract Report D-76-1.)

WORK UNITS. . . . .

1C01 Determinations of Chemical Migration Control Factors. EL, WES. $2,750. Results incorporated into Internal Working Document.

1C03 Effects of Sediment Organic Fractions on the Migration of Various Chemical Constituents During the Disposal of Dredged Material. Cold Regions Research and Engineering Laboratory (CRREL). $126,600. Report published as CR D-76-7.

1C04 Laboratory Study of the Release of Pesticide and PCB Materials to the Water Column During Dredging and Disposal Operations. Envirex, Inc. $103,686. Report published as CR D-75-6.

1C05 Study of Eh, pH, and DO Effects on Chemical Constituent Migration During Open-Water Disposal of Dredged Material. Louisiana State University. $91,171. Report published as CR D-77-4.

1C06 Research Study on the Effect of Dispersion, Settling, and Resedimentation on Migration of Chemical Constituents During Open-Water Disposal of Dredged Material. University of Southern California. $97,565. Report published as CR D-76-1.

1C07 Water Quality Impacts of Aquatic Dredged Material Disposal (Laboratory Investigations)–A Synthesis Report. Report published as TR DS-78-4.

REPORTS PUBLISHED. . . . .

CR D-75-6
(Work Unit 1C04)
Fulk, R., Gruber, D., and Wullschleger, R., "Laboratory Study of the Release of Pesticide and PCB Materials to the Water Column During Dredging and Disposal Operations," December 1975, prepared by Envirex, Inc., Milwaukee, Wisconsin, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD 026 685.

CR D-76-1
(Work Unit 1C06)
Chen, K. Y., et al., "Research Study on the Effects of Dispersion, Settling, and Resedimentation on Migration of Chemical Constituents During Open-Water Disposal of Dredged Materials," February 1976, prepared by the Environmental Engineering Program, University of Southern California, Los Angeles, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A022 144.

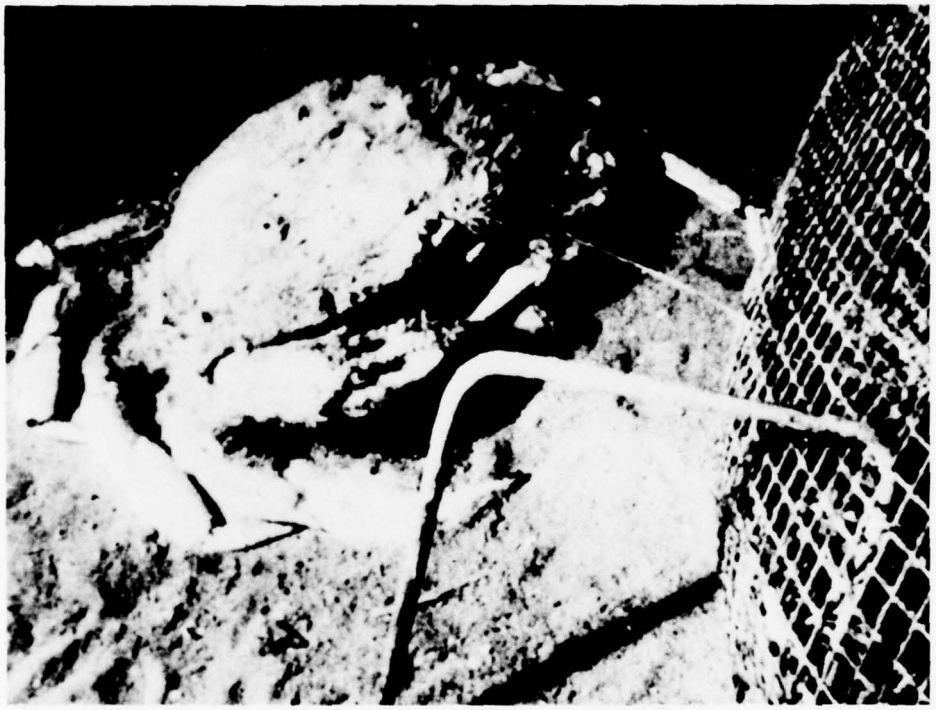
CR D-76-7
(Work Unit 1C03)
Blom, B. E., et al., "Effects of Sediment Organic Fractions on the Migration of Various Chemical Constituents During the Disposal of Dredged Material," May 1976, prepared by the U. S. Army Cold Regions Research and Engineering Laboratory for the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A027 394.

CR D-77-4
(Work Unit 1C05)
Khalid, R. A., et al., "Transformations of Heavy Metals and Plant Nutrients in Dredged Sediments as Affected by Oxidation Reduction Potential and pH," Vol I and II, May 1977. Prepared by Louisiana State University, Baton Rouge, under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A041 460 (Vol I) and AD A041 469 (Vol II).

TR DS-78-4
(Work Unit 1C07)
Burks, S. A., and Engler, R. M., "Water Quality Impacts of Aquatic Dredged Material Disposal (Laboratory Investigations)," Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 735.

EFFECTS OF DREDGING AND DISPOSAL ON AQUATIC ORGANISMS

(Task 1D: Environmental Impacts and Criteria Development Project)



OBJECTIVE. . . . .

—to determine on a regional basis the direct and indirect effects on aquatic organisms due to dredging and disposal operations—

APPROACH. . . . .

—evaluate through literature synthesis, laboratory simulation, and field investigations the physical and chemical impacts of dredged material on the water column and benthic organisms—

IMPLEMENTATION. . . . .

—12 work units (2 in-house efforts, 8 contracts, 2 interagency agreements) involving a total expenditure of $1,144,110.

—final results published in 11 in-house and contractor-prepared technical reports and 1 Synthesis Report.

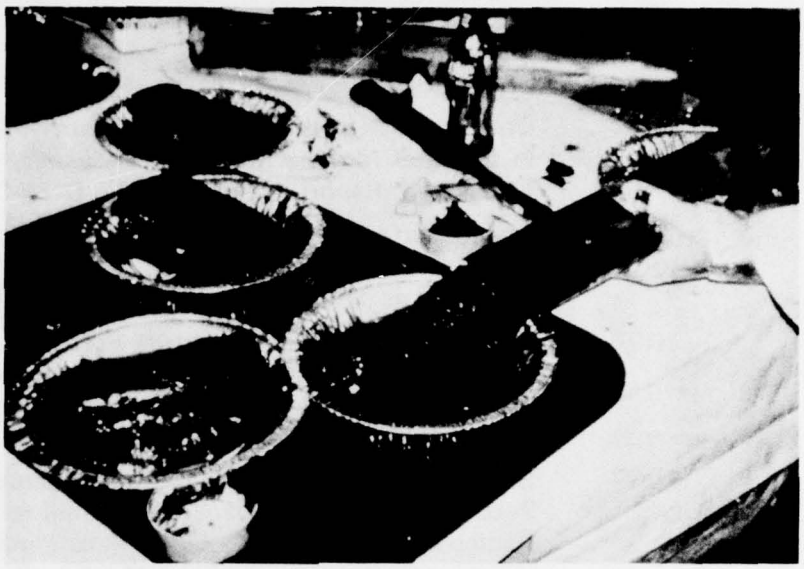
RESULTS. . . . .

Physical Impacts—

Turbidity studies using marine, estuarine, and freshwater organisms showed lethal concentrations of suspended dredged material to be significantly higher (an order of magnitude or more) than concentrations observed in actual dredging and discharge activities. Vertical migration investigations of selected organisms (clams, crabs, and benthic worms) showed them to recover through as much as a metre of like material (i.e., sand on sand, mud on mud) or to have been smothered by as little as a few centimetres covering of unlike material (i.e., sand on mud or mud on sand). Judicious selection of a disposal site to avoid substrate changes is imperative to minimize immediate or long-term physical impacts. Fluid mud results in an acute benthic impact; however, the impacted area recovered to its original nature within 3 months.(See Technical Reports D-77-27, D-77-45, D-78-21, and D-78-35.)

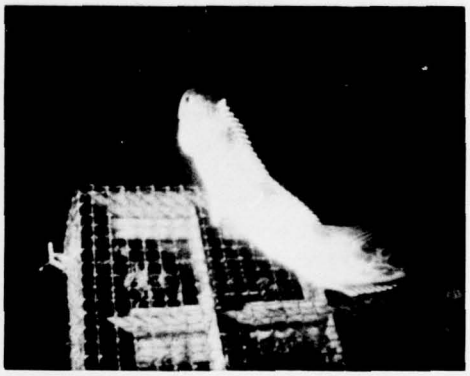
Chemical Impacts—

Chemical constituent uptake studies involved crustaceans, bivalves, and benthic worms exposed and grown in highly contaminated sediments. Little or no uptake of metals from the solid phase was observed. Where some uptake occurred, no clear trends were evident. There was little or no uptake of most hydrocarbons from the solid phase. In some instances there was a slight uptake of a mineral oil fraction. (See Technical Reports D-77-26, D-77-29, D-77-34, and D-78-42.)



Recolonization Investigations—

Field studies demonstrated benthic recolonization of dredged areas and disposal mounds to be rapid for fine-grained sediment and to require up to 3 years for coarse-grained sediments. Recovery in a mudflow (fluid mud) area from pipeline disposal was somewhat more rapid. (See Technical Reports D-77-27 and D-77-45.)



WORK UNITS. . . . .

1D01 Assessment of Aesthetic and Ecological Significance of Turbidity in Various Aquatic Environments. Living Marine Resources, Inc. $46,329. Report published as TR D-78-21.

1D02 Assessment of Equipment, Methodologies, and Institutional Capabilities Available for Conducting or Developing Bioassays. WAPORA, Inc. $49,664. Report published as TR D-78-23.

1D03 Determination of the Vertical Migration Ability of Benthos in Dredged Material Deposits. University of Delaware. $137,745. Report published as TR D-78-35.

1D04 Application of Simulated Ecosystem Modeling to Dredged Material Research (Phase I). EL, WES. $74,553. Report published as TR D-76-3.

1D06 Study of Availability of Sediment-Sorbed Heavy Metals to Benthos with Particular Emphasis on Deposit-Feeding Infauna. Texas A&M Research Foundation. $136,706. Report published as TR D-78-42.

1D07 Study of the Availability of Sediment-Adsorbed Pesticides (DDT, Chlordane, Malathion) to Benthos with Particular Emphasis on Deposit-Feeding Infauna. LFE Environmental Analysis Labs. $106,282. Report published as TR D-77-34.

1D08 Design and Establishment of Estuarine Ecosystem Simulations (Phase I). EL, WES. $203,164. Report published as TR D-78-52.

1D09 Effects of Suspended Dredged Material on Aquatic Animals. Bodega Bay Marine Labs. $167,250. Report published as TR D-78-29.

1D10 Effects of Dredging and Dredged Material Disposal on Benthos and the Marine Environment. San Jose State University. $106,662. Report published as TR D-77-27.

1D11 An Evaluation of Oil and Grease Contamination Associated with Dredged Material. Naval Biomedical Research Lab. $72,402. Report published as TR D-77-26.

1D12 Biological Effects of Fluid Mud. VIMS. $13,353. Report published as TR D-77-45.

1D13 Aquatic Organism Impacts of Dredged Material Disposal–A Synthesis Report. Naval Biomedical Research Lab. $30,000. Report published as TR DS-78-5.

REPORTS PUBLISHED. . . . .

TR D-76-3
(Work Unit 1D04)
Hall, R. W., Westerdahl, H. E., and Eley, R. L., "Application of Ecosystem Modeling Methodologies to Dredged Material Research," June 1976, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A027 207.

TR D-77-26
(Work Unit 1D11)
DiSalvo, L. H., et al., "Assessment and Significance of Sediment-Associated Oil and Grease in Aquatic Environments," November 1977, prepared by the Naval Biosciences Laboratory, Oakland, California, under interagency agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 044.

TR D-77-27
(Work Unit 1D10)
Oliver, J. S., et al., "Patterns of Succession in Benthic Infaunal Communities Following Dredging and Dredged Material Disposal in Monterey Bay," October 1977, prepared by the Moss Landing Marine Laboratories, Moss Landing, California, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A049 632.

TR D-77-34
(Work Unit 1D07)
Nathans, M. W., and Bechtel, T. J., "Availability of Sediment-Adsorbed Selected Pesticides to Benthos with Particular Emphasis on Deposit-Feeding Infauna," November 1977, prepared by the LFE Corporation, Richmond, California, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A055 506.

TR D-77-45
(Work Unit 1D12)
Diaz, R. J., and Boesch, D. F., "Impact of Fluid Mud Dredged Material on Benthic Communities of the Tidal James River, Virginia," December 1977, prepared by the Virginia Institute of Marine Science, Gloucester Point, Virginia, under contrct to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 915.

TR D-78-21
(Work Unit 1D01)
Sterne, E. M., and Stickle, W. B., "Effects of Turbidity and Suspended Material on Aquatic Environments; Literature Review," June 1978, prepared by the Department of Biology, University of Wisconsin, and the Department of Zoology and Physiology, Louisiana State University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 035.

TR D-78-23
(Work Unit 1D02)
Rosenberg, D. D., et al., "Considerations in Conducting Bioassays," June 1978, prepared by the Bioassay Laboratory, WAPORA, Inc., under interagency agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

TR D-78-29
(Work Unit 1D09)
Peddicord, R. K., and McFarland, V. A., "Effects of Suspended Dredged Material on Aquatic Animals," July 1978, prepared by the University of California, Bodega Marine Laboratory, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 489.

TR D-78-35
(Work Unit 1D03)
Maurer, D. L., et al., "Vertical Migration of Benthos in Simulated Dredged Material Overburdens; Volume I: Marine Benthos," June 1978, prepared by the College of Marine Studies, University of Delaware at Lewes, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 725.

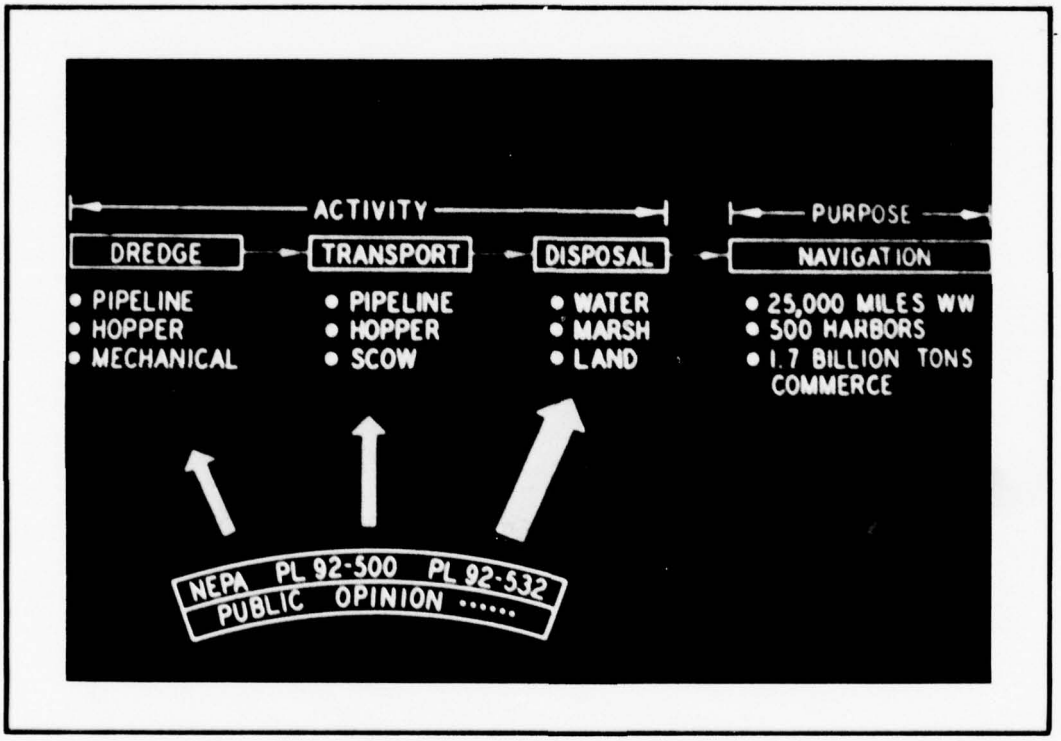
TR D-78-42
(Work Unit 1D06)
Neff, J. W., Foster, R. S., and Slowey, J. F., "Availability of Sediment-Adsorbed Heavy Metals to Benthos with Particular Emphasis on Deposit-Feeding Infauna," August 1978, prepared by the Texas A&M Research Foundation, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 152.

TR D-78-52
(Work Unit 1D08)
Ecosystem Research and Simulation Division, Environmental Laboratory, "Design of a Laboratory Microcosm for Evaluating Effects of Dredged Material Disposal on Marsh-Estuarine Ecosystems," August 1978, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 953.

TR DS-78-5
(Work Unit 1D13)
Hirsch, N. H., DiSalvo, L. H., and Peddicord, R., "Effects of Dredging and Disposal on Aquatic Organisms," August 1978, prepared by the Naval Biosciences Laboratory, University of California, under interagency agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS. No. AD A058 989.

POLLUTION STATUS OF DREDGED MATERIAL

(Task 1E: Environmental Impacts and Criteria Development Project)

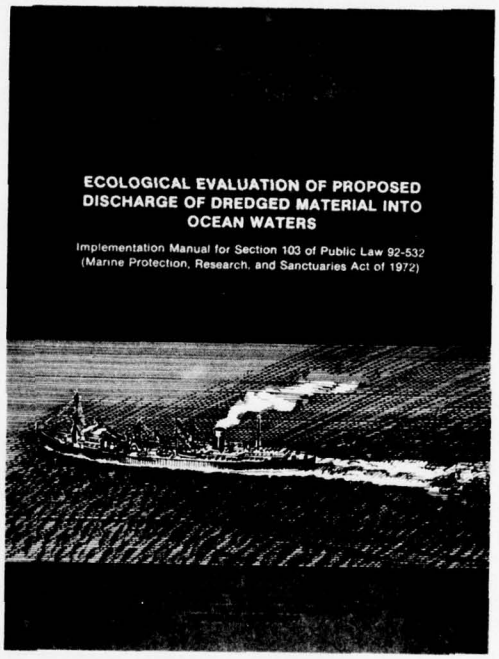


OBJECTIVE. . . . .

—to develop techniques for determining the pollutional properties of various dredged material types discharged under varying environmental conditions—

APPROACH. . . . .

—conduct high-intensity, short-duration laboratory investigations with subsequent field verification to develop physical, chemical, biochemical, and biological assessment techniques to implement Section 404 of PL 92-500 and Section 103 of PL 92-532; place emphasis on water column dissolved and particulate phases and long-term benthic organism effects—



Implementation. . . . .

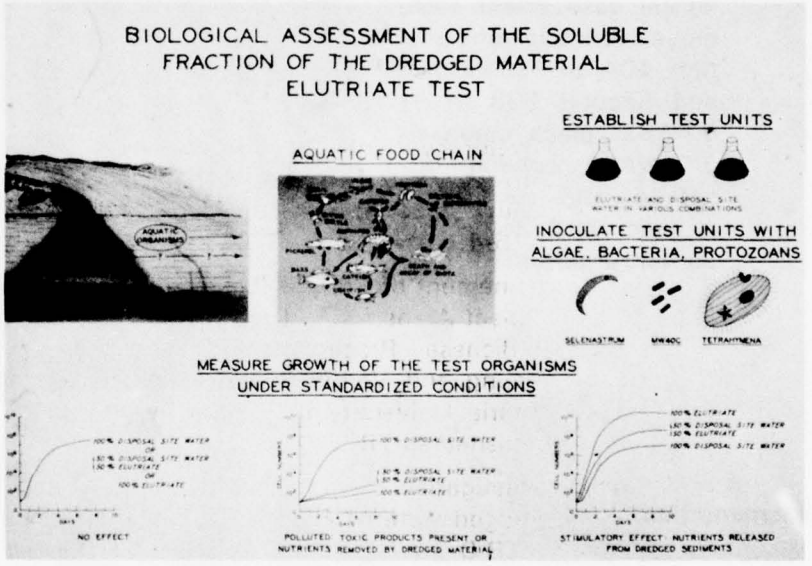
—8 work units (5 in-house, 3 contracts) involving a total expenditure of $1,383,880.

—final results published in 8 in-house and contractor-prepared technical reports and 1 Synthesis Report.

RESULTS. . . . .

Water Column Impacts—

The Standard Elutriate Test adequately predicts mobilization of chemical constituents to the water column. An algal bioassay has been developed for aqueous phase testing and is available for field use. A zooplankton bioassay has been developed for evaluation of the nonfiltered elutriate and for prediction of suspended particulate effects. Field verification of these procedures has shown water column impacts to be virtually insignificant for areas studied. (See Contract Reports D-74-1 and D-75-4 and Technical Reports D-76-7, D-77-3, D-78-45, and D-78-50.)



Benthic Impacts—

Development of a benthic organism bioassay was completed. The procedures, published in an EPA/CE ocean dumping implementation manual, use several different trophic levels of organisms for multiple response evaluation. Field verification of benthic impacts has placed emphasis on contaminant uptake. Results of long-term benthic impacts (i.e., contaminant uptake) have shown this problem to be minimal. (See Technical Reports D-78-45, D-78-49, and D-78-50.)

WORK UNITS. . . . .

1E03	Development of Dredged Material Disposal Criteria. University of Texas at Dallas. $133,018. Literature review and final report published as CR D-74-1 and CR D-75-4.
1E03A/B	Refinement of Current Disposal Criteria, Identification of Subject Areas for Further Development, and Refinement of Bioassay Procedures for Disposal Criteria, and Field Testing and Verification of Dredged Material Disposal Criteria. University of Texas at Dallas. $301,540. Report published as TR D-78-45.
1E04	Investigation of the Partitioning of Various Elements in Dredged Material. EL, WES. $312,600. Report published as TR D-76-7.
1E06	Biological Assessment of the Standard Elutriate Test. EL, WES. $297,220. Report Published as TR D-77-3.
1E07	Long-Term Release of Contaminants from Dredged Material. EL, WES. $69,500. Report published as TR D-78-49.
1E08	Development of Bioassay Methodologies Using Selected Benthic Organisms. EL, WES. $270,000. Report published as TR D-78-50.
1E09	Evaluative Summary of Regulatory Criteria for Public Laws 92-500 and 92-532—A Synthesis Report. EL, WES. Report published as TR DS-78-6.

REPORTS PUBLISHED. . . . .

CR D-74-1 **(Work Unit 1E03)**	Lee, G. F., and Plumb, R. H., "Literature Review on Research Study for the Development of Dredged Material Disposal Criteria," June 1974, prepared by the Institute for Environmental Studies, University of Texas-Dallas, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD 780 755.
CR D-75-4 **(Work Unit 1E03)**	Lee, G. F., et al., "Research Study for the Development of Dredged Material Disposal Criteria," November 1975, prepared by the Institute of Environmental Sciences, University of Texas-Dallas, under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A019 953.
TR D-76-7 **(Work Unit 1E04)**	Brannon, J. M., et al., "Selective Analytical Partitioning of Sediments to Evaluate Potential Mobility of Chemical Constituents During Dredging and Disposal *Operations*," *December* 1976, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A035 247.
TR D-77-3 **(Work Unit 1E06)**	Shuba, P. J., et al., "Biological Assessment of the Soluble Fraction of the Standard Elutriate Test," March 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A040 087.
TR D-78-45 **(Work Unit 1E03A/B)**	Jones, R. A., and Lee, G. F., "Evaluation of the Elutriate Test as a Method of Predicting Contaminant Release During Open-Water Disposal of Dredged Sediments and Environmental Impact of Open-Water Dredged Material Disposal; Volume I: Discussion,"

August 1978, prepared by Environmental Chemistry, University of Texas at Dallas, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A064 014.

Lee, G. F., et al., "Evaluation of the Elutriate Test as a Method of Predicting Contaminant Release During Open-Water Disposal of Dredged Sediments and Environmental Impact of Open-Water Dredged Material Disposal; Volume II: Data Report," August 1978, prepared by Environmental Chemistry, University of Texas at Dallas, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS NO. AD A061 710.

TR D-78-49
(Work Unit 1E07)

Brannon, J. M., Plumb, R. H., and Smith, I., "Long-Term Release of Contaminants from Dredged Material," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A060 814.

TR D-78-50
(Work Unit 1E08)

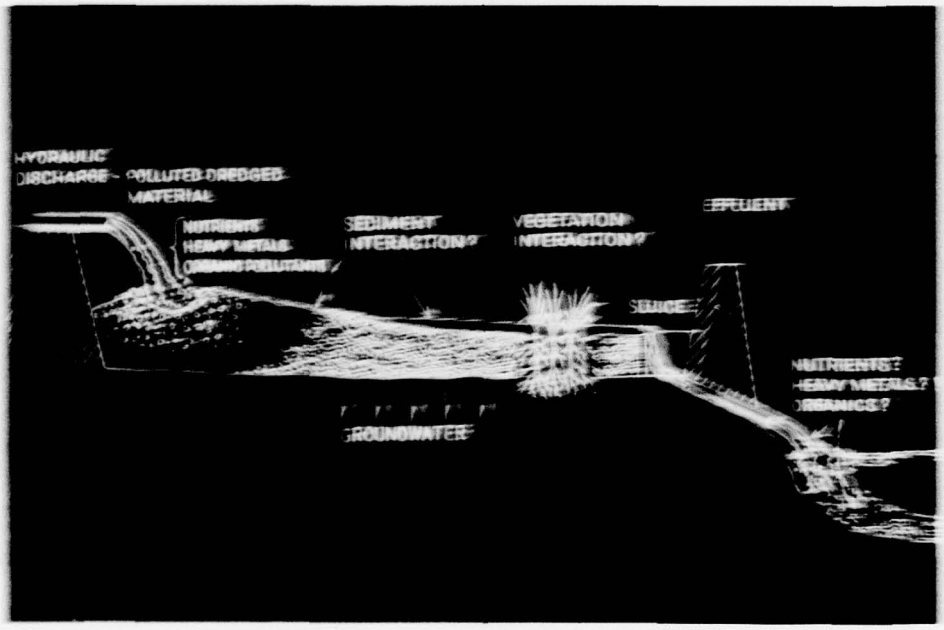
Shuba, P. J., Tatem, H. E., and Carroll, J. H., "Biological Assessment Methods to Predict the Impact of Open-Water Disposal of Dredged Material," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A060 502.

TR DS-78-6
(Work Unit 1E09)

Brannon, J. M., "Evaluation of Dredged Material Pollution Potential," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 724.

CONFINED DISPOSAL AREA EFFLUENT AND LEACHATE CONTROL

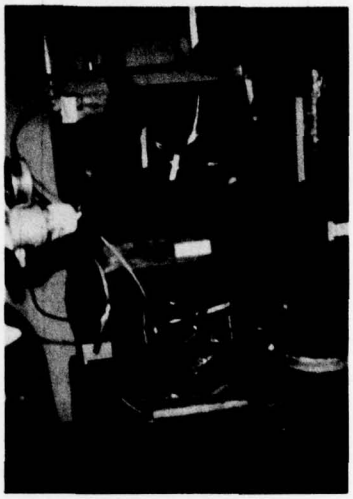
(Task 2D: Environmental Impacts and Criteria Development Project)



OBJECTIVE. . . . .

—to characterize effluents and leachates from confined land disposal facilities, determine whether changes occur in contaminant release over time, and develop methods to predict or control contamination of the surrounding environment—

APPROACH. . . . .



—determine, through field and laboratory investigations, ecological problems created from surface runoff or leachate movement from confined dredged material disposal areas; investigate site-specific hydrological, geological, and physical conditions; monitor nutrients, trace metals, and chlorinated and petroleum hydrocarbons in solid and liquid phases; determine parameters and conditions that indicate short- and long-term impacts—

IMPLEMENTATION. . . . .

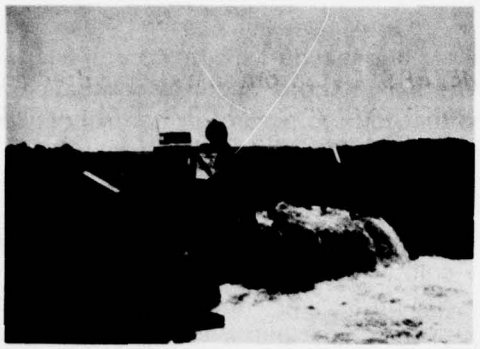
—6 work units (1 in-house, 4 contracts, 1 interagency) involving a total expenditure of $533,964.

—final results published in 1 in-house report, 3 contractor-prepared reports, and 1 Synthesis Report.

RESULTS. . . . .

Effluent Characterization—

EFFLUENTS VERSUS BACKGROUND WATER. Effluents collected from 11 confined disposal areas were found to differ in several ways from ambient surface background water. Average soluble concentrations of ammonium nitrogen and manganese were more than 25 times higher in the effluent samples. Other soluble phase contaminants were generally at comparable levels (less than threefold difference) in both effluent and surface background water samples.



Most contaminants were mainly associated with the suspended solids fraction of effluents, at levels well below the levels of suspended solids added to the receiving waters. Total PCB's in effluents from brackish water sites were comparable to background water levels; freshwater site effluents were 10 times background. Total DDT was 2 times higher in the receiving waters at brackish water sites, while the freshwater site effluents contained 25 times the total DDT level in the receiving waters. The data indicate that total PCB's and DDT could generally be removed to less than 10-ppb levels with proper retention. Soluble oil and grease, orthophosphate, and dissolved organic carbon in effluents were at background levels. Dissolved oxygen in effluents from brackish and freshwater sites averaged 4.8 and 7.7 ppm, respectively.

INFLUENTS VERSUS EFFLUENTS. Influent-effluent monitoring at 10 confined disposal areas showed that, with proper slurry retention, land containment of dredged material can effectively immobilize most contaminants to levels below present criteria. Organic and metal contaminants were associated with the solids fraction, and a close relationship between contaminant and solids removal was noted. Only total potassium, magnesium, ammonium nitrogen, manganese, mercury, and DDE consistently showed removal efficiencies of less than 90 percent. Geochemical phase partitioning data indicated that many metal cantaminants revert to potentially more bioavailable solid-phase forms or complexes. Zinc and copper showed slight trends toward increased mobility at specific upland sites. Mercury, because of its observed association with small particles, should be carefully monitored if at high levels. Total effluent analysis for predictive testing may be meaningful, although these data indicate the need to better define the chemical forms of contaminant elements if criteria are to be based on analytical data. Low dissolved oxygen levels in effluents were found to be accentuated by turbulent flow through loose sediment and a short residence time and high nutrient levels in ponded water. Proper retention of dredged material in land containment areas is necessary to remove suspended solids and reduce most contaminants to background levels. However, the reported data suggest that extremely long retention, in the order of several weeks, may not be desirable.

Leachate Characterization—

LABORATORY LYSIMETERS. Data from tests using dredged material from five field sites, each overlying a 1-foot-thick layer of uncontaminated soil, indicated that leachate quality may be governed by both the dredged material and underlying soils. The dredged material interstitial water showed small time-dependent increases in pH, Eh, total organic carbon, alkalinity, and manganese. Soluble phosphorus remained stable while soluble organic and ammonium nitrogen, copper, calcium, sodium, and potassium showed continual decreases in concentration. Cadmium and zinc trends were variable. Soluble PCB's were not detected (<0.1 ppb), although total chlorinated pesticides were occasionally found at 2-ppb levels. The soils served as a source for soluble iron, manganese, calcium, potassium, nitrate, and total Kjeldahl nitrogen. Soluble cadmium, copper, and lead were generally totally removed by the soil; sodium, potassium, and calcium were greatly decreased; however, with time the decrease was less. The chlorinated pesticides and PCB's in final leachates were nil.

The mobility of constituents was governed by the inherent properties of the soils and not by the nature of the leaching solutions. Groundwater and soil conditions should be carefully considered when choosing a prospective land disposal site. Correlation with field studies indicates that the column studies duplicate the mobility of the major ions and represent a worst-case simulation.

FIELD LEACHATE STUDY. Sediment and water samples were obtained at four field sites and at four depths (a) within the disposal area, (b) at off-site monitoring stations, and (c) at off-site background stations.

Leachate quality is a function of the nature of the disposed dredged material and environmental conditions of the site soils. In general, the study found that sodium, potassium, calcium, magnesium, chloride, total organic carbon, alkalinity, and manganese in leachates from disposal areas may impact local groundwater. Low concentrations of cadmium, copper, iron, mercury, lead, zinc, nickel, and phosphate may reach groundwaters, but the levels should not pose water quality problems. Certain sites showed localized high levels of certain contaminants, including nickel, cadmium, and copper. The major contaminants at the brackish water sites appeared to be the salts of major ions.

WORK UNITS. . . . .

2D01 Physical and Chemical Characterization of Contaminated Dredged Material Influents, Effluents, and Sediments in Confined Upland Disposal Areas. EL, WES. $134,000. Report published as TR D-78-24.

2D02 A Study of Leachate from Dredged Material in Upland Disposal Sites and/or in Productive Uses. SCS Engineers. $158,094. Report published as TR D-78-20.

2D03 Monitoring of Trace Constituents During PCB Recovery Dredging Operations, Duwamish Waterway. EPA 910/9-77-039, Aug 1977. EPA Region X, and Seattle District, CE. $17,012. No final report published. Results presented in other reports.

2D04 Characterization of Confined Disposal Area Influent and Effluent Particulate and Petroleum Fractions. University of Southern California. $32,708. Report published as TR D-78-16.

2D05 Physical and Chemical Characterization of Dredged Material Sediments and Leachates in Confined Land Disposal Areas. University of Southern California. $174,699. Report published as TR D-78-43.

2D06 Confined Disposal Area Effluent and Leachate Control—A Synthesis Report. University of Southern California. $17,451. Report published as TR DS-78-7.

REPORTS PUBLISHED. . . . .

TR D-78-16
(Work Unit 2D04)

Lu, J. C. D., et al., "Characterization of Confined Disposal Area Influent and Effluent Particulate and Petroleum Fractions," May 1978, prepared by the Environmental Engineering Program, University of Southern California, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 371.

TR D-78-20
(Work Unit 2D02)

Mang, J. L., et al., "A Study of Leachate from Dredged Material in Upland Areas and/or in Productive Uses," June 1978, prepared by SCS Engineers under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 897.

TR D-78-24
(Work Unit 2D01)

Hoeppel, R. E., et al., "Physical and Chemical Characterization of Dredged Material Influents and Effluents in Confined Land Disposal Areas," June 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A057 460.

TR D-78-43
(Work Unit 2D05)

Yu, K. Y., et al., "Physical and Chemical Characterization of Dredged Material Sediments and Leachates in Confined Land Disposal Areas," August 1978, prepared by the Environmental Engineering Program, University of Southern California, Los Angeles, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 846.

TR DS-78-7
(Work Unit 2D06)

Chen, K. Y., et al., "Confined Disposal Area Effluent and Leachate Control (Laboratory and Field Investigations)," October 1978, prepared by the University of Southern California, Los Angeles, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 882.

EFFECTS OF MARSH AND TERRESTRIAL DISPOSAL

(Task 2A: Habitat Development Project)

OBJECTIVE. . . . .

—document and describe the specific short-term and more general long-term effects of confined and unconfined dredged material disposal for wetland and upland habitat development—

APPROACH. . . . .

—determine, through field and laboratory studies, the changes in chemical composition, structure, and function of biological communities in response to dredged material disposal operations designed for habitat development—

IMPLEMENTATION. . . . .

—9 work units assigned to Task 2A and 4 reassigned from Task 4A (8 in-house efforts, 5 contracts) involving a total expenditure of $978,709.

—final results published in 9 in-house and contractor-prepared technical reports and 2 Synthesis Reports.

RESULTS. . . . .

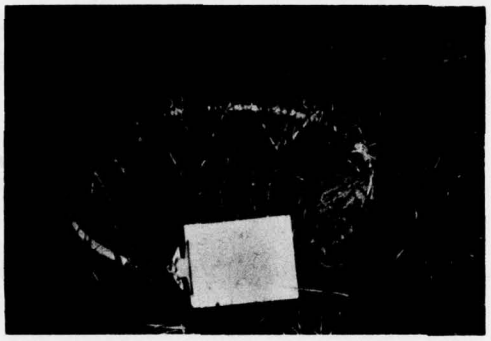
Nutrient and Heavy Metal Cycling—

This work unit provided a comprehensive review and summary of existing information (through 1975) about nutrient and heavy metal cycles in marsh-estuarine systems, identifying the roles of marsh and estuarine nonbiological and biological components. (See TR D-78-3.)

Vegetation Succession—

An inventory and description of development of vegetation on dredged material islands in the upper Mississippi River was accomplished. A plant colonization pattern is described by dominant pioneer grasses for long periods of time. Vines and shrubs slowly encroached on the material from the fringes of surrounding alluvial forests. (See TR D-77-31.)

Experimental Disposal on Marsh—



Experiments in a Georgia *Spartina alterniflora* community containing fiddler-crabs and marsh snails indicated that up to 9 inches of dredged material placed on the marsh had no noticeable effect on marsh plant growth; crab populations were able to survive smothering up to the 9-inch depth. Marsh snails were smothered by the dredged material but rapidly recovered when dredged material depths were less than 6 inches; their reinvasion was related to the reestablishment of marsh grass cover and the proximity of adjacent invertebrate populations. Elevational considerations, probably related to hydrographic influences on the marsh surface and associated sediment compaction and nutrient cycling, are probably the most important factors affecting marsh recovery following dredged material disposal. (See TR D-78-38.)

Ecological Considerations, A Synthesis—

The relationship between natural physical forces affecting geology, hydrology, and climate, and ecological principles of succession, competition, and predation are compatible with the concept of habitat development using dredged material. Emphasis must be placed on sound planning to avoid the development of habitats that are incompatible with localized project and broader area management objectives. Important considerations include the planning of habitats that function to support established fish and wildlife management objectives. These include the understanding of target animal-habitat interactions and the awareness of operations with potential for chemical contaminant mobilization or displacement of valuable, difficult-to-replace habitat types. (See TR DS-78-15.)

Considerations for Habitat Development, A Synthesis—

An overview of habitat development alternatives using dredged material resulted in an introduction to the feasibility considerations that include dredged material characterization, site selection,

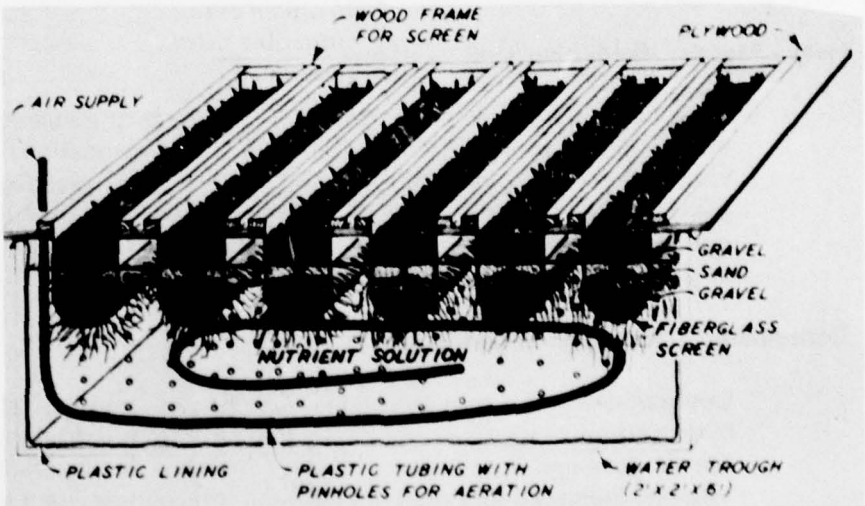
engineering, cost, sociopolitical implications, and environmental impact assessment. Procedural guidance for considering upland, marsh, island, and aquatic habitat development was prepared. (See TR DS-78-19.)

Heavy Metals: Uptake and Substrate Characterization—

Greenhouse and laboratory findings demonstrated that Eh, pH, and salinity affect the availability to marsh plants of sediment-bound metals. Based on the results of this research, it will be possible to select disposal options that minimize the possibility of heavy metal uptake from highly contaminated dredged material. (See TR D-77-40.)

Heavy Metals: Hydroponics—

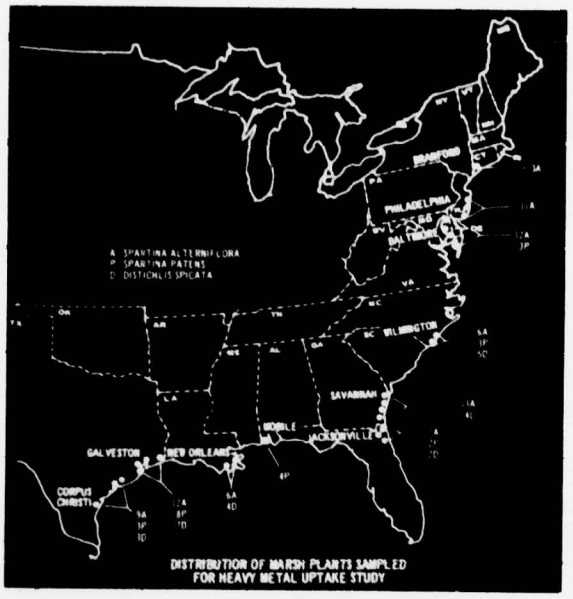
Eight marsh plants were exposed, in hydroponic solution, to heavy metals. *Cyperus esculentus, Spartina patens, Distichlis spicata,* and *Spartina alterniflora* showed significant potential for accumulating heavy metals, while *Scirpus validus, Scirpus robustus, Triglochin maritima,* and *Spartina foliosa* did not. Lead and chromium were taken into the roots of all species but were not translocated to the leaves and stems. Cadmium, zinc, and nickel were accumulated in varying amounts in the leaves and stems of several species. (See TR D-76-5.)



HYDROPONIC SYSTEM FOR HEAVY METAL UPTAKE STUDY

Heavy Metals: Field Verification—

Marsh plants growing voluntarily on disposal sites were sampled at 29 locations along the Gulf and Atlantic coasts. Little heavy metal uptake, beyond that found in natural marshes, was noted. (See TR D-78-6.)



DISTRIBUTION OF MARSH PLANTS SAMPLED FOR HEAVY METAL UPTAKE STUDY

Heavy Metals: Predictive Methodologies—

A procedure was developed to predict, prior to the selection of the habitat development alternative, uptake and translocation of selected heavy metals from dredged material into the green tissues of marsh plants. This technique, a DPTA extraction, will be a useful decision-making tool where certain types of heavy metal contamination are suspected. (See TR D-78-6.)

Contaminants in Dredged Material—

Comparisons of concentrations of heavy metals, chlorinated hydrocarbon pesticides, and PCB's in plants from a dredged material marsh development site and natural marshes in the James River, Virginia, indicated that dredged material total contaminant levels cannot be used to predict potential plant uptake. Results suggest that natural physical and chemical processes characteristic of marshes effectively immobilize some metals and reduce their transfer to marsh

vegetation. Degradation and volatilization of some chlorinated hydrocarbon pesticides may be increased by marsh conditions and plant surface uptake of volatilized pesticides may be a contamination pathway. (See TR D-77-23, Appendix E.)

WORK UNITS. . . . .

2A01, 2B01	Methodology for Assessing the Social, Economic, and Environmental Effects of Dredged Material Disposal on Marsh and Upland Areas. Battelle Memorial Institute, Columbus. $119,620. Report incorporated into Internal Working Document.
2A02, 2B02	Collection and Assessment of Data on Land and Coastal Disposal Sites and Selection of Initial Test Sites. Interlaboratory team, WES. $140,650. Report incorporated into Internal Working Document.
2A04	Environmental Impact of Dredging at Crosby Slough. University of Wisconsin at LaCrosse. $25,274. Report published as MP D-78-2.
2A05	Marsh-Estuarine Nutrient and Heavy Metal Cycling. EL, WES. $92,150. Report published as TR D-78-3.
2A06	Study of Vascular Plants on Dredged Material Sites in Pool 8, Upper Mississippi River. University of Wisconsin at LaCrosse. $7,391. Report published as TR D-77-31.
2A07	Effect of Dredged Material Deposition on Short Form *Spartina alterniflora* Marsh. University of Georgia, Marine Resources Extension Center. $87,839. Report published as TR D-78-38.
2A08	Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations—A Synthesis Report. EL, WES. $25,000. Report published as TR DS-78-15.
2A09	Habitat Development with Dredged Material: Feasibility Considerations and Criteria for Selection of Management Alternatives—A Synthesis Report. EL, WES. $10,000. Report published as TR DS-78-19.
2A10	Survey of Potential Medical and Veterinary Diseases at Habitat Development Sites. EL, WES. Report published as MP D-78-1.

4A06 Physiological Response of Marsh Plants to Environmental Stress. (In Part.) Louisiana State University. $238,907. Report published as TR D-77-40.

4A11L James River (Virginia) Field Study. Organohalide Study at Windmill Point Marsh Development Site. EL, WES. $33,955. Report published as TR D-77-23, Appendix E.

4A15A Heavy Metal Uptake by Marsh Grasses (Phase I). EL, WES. $87,000. Report published as TR D-76-5.

4A15B Heavy Metal Uptake by Marsh Grasses (Phase II). EL, WES. $144,178. Report published as TR D-78-6.

REPORTS PUBLISHED. . . . .

TR D-76-5 (Work Unit 4A15A) Lee, C. R., et al., "A Hydroponic Study of Heavy Metal Uptake by Selected Marsh Species," June 1976, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A033 224.

TR D-77-23, Appendix E (Work Unit 4A11L) Lunz, J. D., "Habitat Development Field Investigations, Windmill Point Habitat Development Site, James River, Virginia; Appendix E: Environmental Impacts of Marsh Development with Dredged Material: Metals and Chlorinated Hydrocarbon Compounds in Marsh Soils and Vascular Plant Tissues," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 170.

TR D-77-31 (Work Unit 2A06) Ziegler, S. R., and Sohmer, S. H., "The Flora of Dredged Material Sites in Navigation Pool 8 of the Upper Mississippi River," November 1977, prepared by the University of Wisconsin, LaCrosse, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 778.

TR D-77-40 (Work Unit 4A06) Gambrell, R. P., et al., "Trace and Toxic Metal Uptake by Marsh Plants as Affected by Eh, pH, and Salinity," December 1977, prepared by the Center for Wetland Resources, Louisiana State University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 914.

TR D-78-3
(Work Unit 2A05)

Gunnison, D., "Mineral Cycling in Salt Marsh-Estuarine Ecosystems; Ecosystem Structure, Function, and General Compartmental Model Describing Mineral Cycles," January 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A052 737.

TR D-78-6
(Work Unit 4A15B)

Lee, C. R., et al., "Prediction of Heavy Metal Uptake by Marsh Plants Based on Chemical Extraction of Heavy Metals from Dredged Material," February 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A054 129.

TR D-78-38
(Work Unit 2A07)

Reimold, R. J., Hardisky, M. A., and Adams, P. C., "The Effects of Smothering a *Spartina alterniflora* Salt Marsh with Dredged Material," July 1978, prepared by the Marine Extension Service, University of Georgia, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 366.

MP D-78-1
(Work Unit 2A10)

Simmers, J. W., "A Survey of Potential Medical and Veterinary Diseases at Habitat Development Field Sites," July 1978, Environmental Laboratory, U. S. Army Enginer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 845.

MP D-78-2
(Work Unit 2A04)

Held, J. W., "Environmental Impact of Dredging Disposal on the Upper Mississippi River at Crosby Slough," August 1978, prepared by the River Studies Center, University of Wisconsin, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 847.

TR DS-78-15
(Work Unit 2A08)

Lunz, J. D., Diaz, R. J., and Cole, R. A., "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A067 828.

TR DS-78-19
(Work Unit 2A09)

Smith, H. K., "An Introduction to Habitat Development on Dredged Material," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A067 202.

MARSH DEVELOPMENT

(Task 4A: Habitat Development Project)

OBJECTIVE. . . . .

—to develop, test, and evaluate the environmental, economic, and engineering feasibility of using dredged material as a substrate for marsh development—

APPROACH. . . . .

—conduct field studies at selected sites to test the problems and techniques of marsh development under various substrate, salinity, tidal, and climatic conditions; evaluate, under laboratory and field conditions, the productivity of both major and minor marsh plant species, their substrate selective properties, and their patterns of ecological succession—

IMPLEMENTATION. . . . .

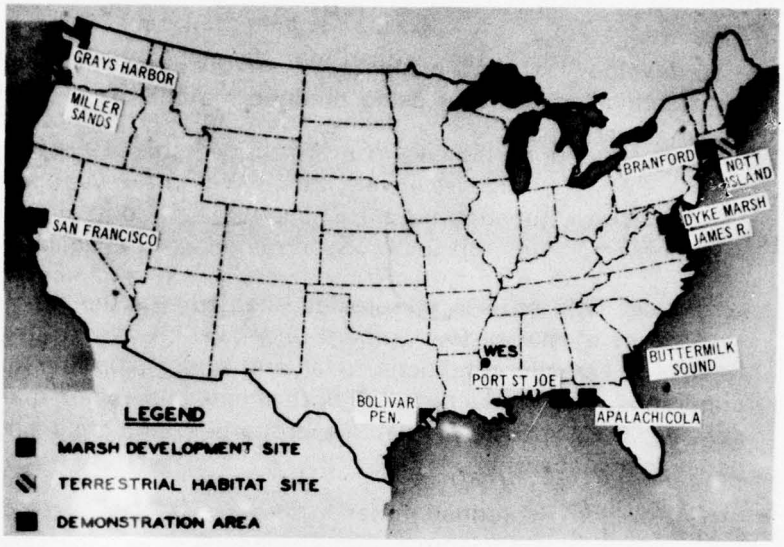
—61 work units (24 in-house efforts, 35 contracts, 2 interagency agreements), involving a total expenditure of $4,085,165.

—final results published in 42 reports, including 3 Synthesis Reports and 7 field site reports with a total of 16 appendixes.

RESULTS. . . . .

Field Sites—

Marsh habitat was successfully established at dredged material disposal sites in Virginia, Georgia, Florida, Texas, California, and Oregon. Two of these sites (Texas and Oregon) included upland habitat development studies and these aspects are discussed under Task 4B. Items under consideration in Task 4A included site selection, stabilization of the newly placed substrate, retention and protective structures, species selection, planting techniques, fertilization requirements, marsh productivity and succession, wildlife use, contaminant mobility, and an assessment of the environmental impact of marsh development.

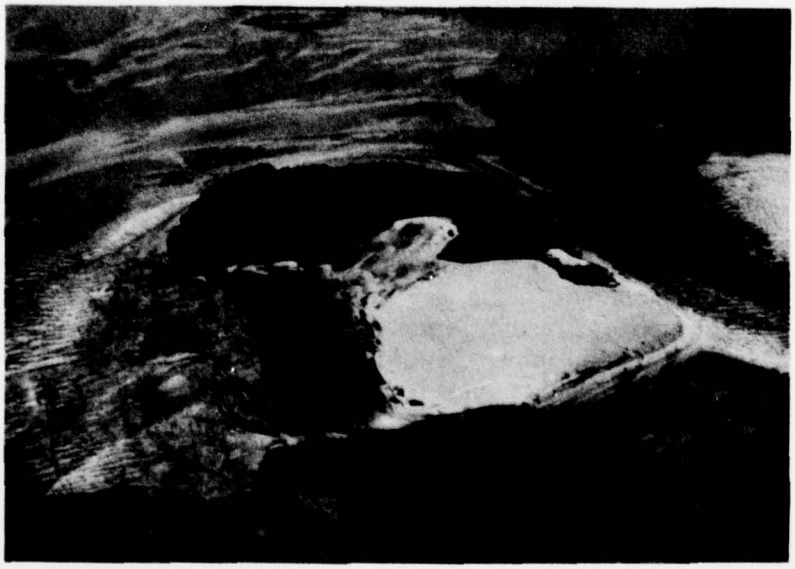


DYKE MARSH. Detailed design was completed for restoration of portions of Dyke Marsh on the Potomac River near Alexandria, Virginia. Natural marsh in this area was largely destroyed by sand and gravel mining operations. Initiation of construction at this site has been delayed because of coordination activities. (See TR D-77-13.)

WINDMILL POINT. A 20-acre freshwater marsh island complex was developed in the James River, just west of Prince George County, Virginia. Dredged material contaminated by agricultural and industrial chemicals including pesticides, polychlorinated biphenyls, and metals

was confined within a hydraulically placed sand dike. Natural invasion by over 100 different types of wetland and upland plants occurred within 6 months after dredged material disposal. Results of studies designed to compare the Windmill Point experimental habitat with similar natural habitats indicated that: (a) A short-term release of dissolved and particulate contaminants occurred during and immediately following site development. Within a 2-year period, water quality characteristics were comparable. (b) Contaminant levels in the plants growing on the dredged material were similar to levels in natural marsh plants despite differences in sediment chemistry. (c) The dredged material marsh provided habitat to the fish community that was equal to or exceeded the value of the preexisting shallow bottom. (d) The experimental marsh provided protective and reproductive cover and food for a variety of important fish and wildlife. (See TR D-77-23.)

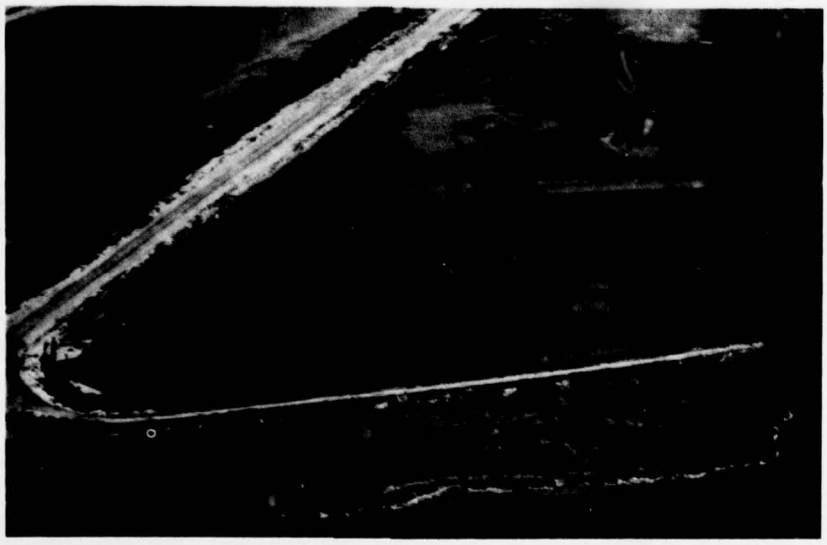
BUTTERMILK SOUND. A 3-acre brackish water marsh was established on sandy dredged material along the Intracoastal Waterway in Buttermilk Sound, Georgia. The purpose of this study was to determine the productivity and success of establishment, by both seeding and sprigging, of eight marsh species at three tidal elevations under five fertilizer regimes. Elevation and the associated amount of inundation appeared to be the controlling factor in marsh development, both for planted and invading species. *Spartina alterniflora* was the only species to grow in the lowest tidal elevation. The sandy substrate was enriched in quality over the period of the study, in some plots approaching the appearance of natural marsh soils. (See TR D-78-26.)



APALACHICOLA BAY. A small marsh development project to test the efficacy of planting *Spartina alterniflora* sprigs on poorly consolidated fine-grained marine sediments was conducted near Apalachicola, Florida. *Spartina patens* was planted on sandy dredged material at a higher elevation. Productivity and elevational relationships were evaluated as well as operational constraints encountered in the use of mechanical equipment on poorly consolidated dredged material. Both species established rapidly, giving the appearance of a natural marsh. (See TR D-78-32.)

BOLIVAR PENINSULA. A 9-acre salt marsh was established on sandy dredged material at Bolivar Peninsula near Galveston, Texas. The objectives of the study were to determine effective plant propagation techniques for salt marsh establishment and to examine the effectiveness of a sandbag dike positioned to reduce high wave energy at the study area. Benthic and nektonic colonization of the site, plant development along an intertidal elevation gradient, and plant responses to various rates of fertilization were also evaluated. Marsh plant establishment was generally successful, with elevation zone and form of propagule the critical factors. *Spartina alterniflora* grew best below mean high tide and *Spartina patens* grew best above that level. Sprigs were more effective than seeds. Protection afforded by the sandbag dike was considered necessary in this location. Resource value of the site has increased as a result of habitat development activities. (See TR D-78-15.)

SALT POND 3. A study of marsh development on confined dredged material in an abandoned 10-acre salt pond in South San Francisco Bay demonstrated that a *Spartina foliosa* marsh can be established within 2 years. Aspects of plant spacing, substrate preparation, plant elevation, planting season, planting efficiency, and natural colonization were explored; cost estimates were prepared for the various



AD-A074 531 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 13/3
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propagation operations. Planting recommendations were derived for the San Francisco Bay area as to proper elevational levels and intertidal flow, spacing of sprigs, and planting techniques. (See TR D-78-57.)

MILLER SANDS. A 9-acre intertidal portion of a sandy dredged material island in the Columbia River near Astoria, Oregon, was planted with two species of freshwater marsh plants, *Carex obnupta* and *Deschampsia caespitosa*. The purposes were to determine the feasibility of marsh establishment in the Pacific Northwest by testing various marsh establishment techniques and to assess the environmental impacts of marsh development. Plant survival and production, wildlife usage, and benthic and nektonic colonization were also studied. Results indicated that marsh establishment is feasible in this area, using sprigged propagules and protection from erosive forces. Propagation by seeding was unsuccessful. Planted areas were fairly well established one year after planting and were beginning to invade unplanted areas. Fertilization had little effect on successful establishment or production of planted species. (See TR D-77-38.)

Primary Productivity—

The net annual aerial primary productivity of major and minor salt marsh plants was studied in Maine, Delaware, Georgia, and Louisiana. Contrary to conventional ecological thought, latitude has little impact on species productivity and several species formerly considered of questionable value were found to equal or exceed the productivity of *Spartina alterniflora*. Frequently used methods for determining primary productivity were tested and compared with the conclusion that no methodology exists that will produce consistently valid results between species and locations. Development of a community approach that considers species morphology and geographic location appears to be necessary. (See TR D-77-36 and TR D-77-44.)

Underground Biomass Dynamics—

Studies of the underground biomass dynamics of selected salt marsh species were conducted to compare and characterize natural and man-made marsh systems, document underground productivity and turn-over rates, and describe species substrate selectivity. Three belowground biomass profiles were identified as typical of a given marsh species. Comparisons of natural marsh profiles with those of man-made marshes should provide a rapid indication of the "naturalness" or maturity of a marsh developed on dredged material. Underground production of several marsh species equals or exceeds aboveground production and must be considered a major component in the evaluation of marsh productivity. (See TR D-77-28.)

Ecological Succession—

Extensive evaluation of the ecological successional patterns of *Spartina alterniflora, S. patens,* and *Distichlis spicata* indicates that radiation, temperature, tidal inundation, elevation, and salinity are the critical factors in determining productivity and natural succession. A computer model, designed to predict the productivity of a salt marsh given these critical factors, has been developed and can be used in the design of man-made marshes. (See TR D-77-35.)

Seed Viability—

Laboratory tests and a brief state-of-the-art review were conducted to determine the viability and germination requirements of seed from 13 marsh plant species and to determine proper methods of seed storage and handling techniques for maximizing viability. Selected species that exhibited considerable dormancy were also subjected to various gas and hormone treatments in an effort to break seed dormancy. Optimum storage conditions, thermoperiods, and periods required for germination were determined for each of the species tested. These parameters can be useful for indicating the feasibility of using certain plant species in marsh establishment projects when direct seeding is desired. (See TR D-78-51.)

Survey of Recent and Planned Marsh Establishment Work—

Recent and planned marsh establishment projects throughout the contiguous United States between 1970 and 1976 were surveyed and practical guidelines for marsh development were developed. Excluding DMRP investigations, 105 projects were completed and 14 projects were planned by early 1977. Practical guidelines for marsh establishment, including project design and planning, plant propagation techniques, and area management requirements, were discussed.

Field Bioassay—

A preliminary test of a field technique designed to identify the suitability of dredged material for marsh plant establishment and its capability for transferring contaminants to marsh plants was conducted. The technique, called the Bucket Evaluation Test (BET), needs refinement before routine application is attempted but appears feasible and potentially practical. (See MP D-78-6.)

Guidelines for Dredged Material Placement—

A systematic set of guidelines for establishing new marshes from dredged material under a variety of situations and constraints was developed. Engineering and operational practices and problems were considered in the development of these guidelines. The most critical factors in marsh development were determined to be the elevation, protection, and confinement of the dredged material. (See CR D-75-2.)

Establishment Techniques—

Factors affecting plant establishment in saltwater and freshwater marshes were examined under controlled greenhouse conditions. Propagation techniques, propagule types, tidal regimes, and substrate types were studied. In general, propagation by sprigs was more successful than propagation by seeds, tubers, or rhizomes. Fine-grained dredged material was usually more productive than coarse-grained material as the former contained more available nutrients. Salinity was indicated as a possible limiting factor in establishing brackish marsh plants. (See TR D-77-2.)

Identification of Criteria for Marsh Development and Potential Application Sites—

Biophysical and socioeconomic data and rationale needed to evaluate potential marsh development sites were examined and tested at 50 project areas throughout the United States. This study indicated that careful application of design techniques provides considerable flexibility in the marsh development alternative. (See CR D-76-2.)

Retaining Structures—

Guidelines for selecting and evaluating in-water retaining and/or protective structures for use in habitat development were developed, including necessary design considerations and constraints. General concepts for design were outlined and sources of information pertaining to detailed design referenced. Case histories of retention and/or protective structures that were used in habitat development activities in Texas and Virginia were evaluated from an economic and technical standpoint. (See TR D-78-31.)

WORK UNITS. . . . .

4A01	Study of Identification of Relevant Criteria and Survey of Potential Application Sites for Artificial Habitat Creation. Coastal Zone Resources Corporation. $86,438. Report published as CR D-76-2.
4A03	State-of-the-Art Survey and Evaluation of Marsh Plant Establishment Techniques. University of Michigan. $24,967. Report published as CR D-74-9.
4A04A1	Primary Productivity of Minor Marsh Plants in Delaware, Georgia, and Maine. University of Georgia Marine Institute. $211,559. Report published as TR D-77-36.
4A04A2	Underground Biomass Dynamics and Substrate Selective Properties of Atlantic Coastal Salt Marsh Plants. University of Georgia Marine Institute. Financed within 4A04A1. Report published as TR D-77-28.
4A04B	Common Marsh Plant Species of the Gulf Area, Volume 1: Productivity. Volume 2: Growth Dynamics. Dept. of Marine Sciences, Louisiana State University. $263,277. Report published as TR D-77-44.
4A05	Modeling of Ecological Succession and Production in Estuarine Marshes. Dept. of Environmental Sciences, University of Virginia. $188,646. Report published as TR D-77-35.
4A07	Concept Development and Economic and Environmental Compatibility Analyses of Underwater and/or Floating Dredged Material Retaining and Protective Structures. EL, WES. $51,159. No report planned; data input to Work Unit 4A07A.
4A07A	Development and Design Concepts for In-Water Retaining and Protective Structures for Marsh Development. CERC. $63,700. Report published as TR D-78-31.
4A08	Development of Guidelines for Material Placement in Marsh Creation. Center for the Environment and Man, Inc. $62,884. Report published as CR D-75-2.
4A09	Pregermination Requirements and Establishment Techniques for Salt Marsh Plants. EL, WES. $253,100. Report published as MP D-77-1.

4A10	Branford Harbor Marsh Development Site, Connecticut.
4A10A	Methods of Material Confinement at Branford Harbor. Massachusetts Institute of Technology. $2,350. Combined with 4A10B.
4A10B	Technical Assistance for Branford Harbor Systems. Massachusetts Institute of Technology. $9,625. Report incorporated in Internal Working Document.
4A10C	Assessment of Preoperational Environmental Conditions at Branford Harbor. Marine Sciences Institute, University of Connecticut. $170,700. Report incorporated in Internal Working Document.
4A10D	Marsh Grass Seed Collection, Storage, and Testing. Environmental Concern, Inc. $4,200. Report incorporated in Internal Working Document.
4A10E, F,G,H	Documentation of Political and Social Factors Affecting the Site. Ms. Sue Richardson, Dr. Fred Grupp. $9,805. No report planned.
4A10I	Cost Estimate for Construction of Containment Area. New England Division, CE. $1,000. No report planned.
4A10J	Maintenance Dredging Project. Final Environmental Impact Statement. New England Division, CE, WES. $1,800. No report planned.
4A10K	Habitat Development Field Investigations, Branford Harbor Marsh Development Site, Branford, Connecticut. Summary report. WES. Report incorporated in Internal Working Document.
4A11	Windmill Point Marsh Development Site, James River, Virginia.
4A11A	Soils Exploration and Testing, Windmill Point. Soil and Material Engineers, Inc. $30,331. No report planned.
4A11B	Dike Design, Windmill Point. Dr. Robert Y. K. Cheng, Old Dominion University. $4,820. Report incorporated in Internal Working Document.
4A11C	Preoperational Assessment, Windmill Point. Virginia Institute of Marine Sciences. $10,725. Report published as Appendix A to site report (TR D-77-23).

4A11D Preoperational Assessment, Windmill Point. Old Dominion University. $9,805. Combined with 4A11G and 4A11H. Report published as Appendix F to site report (TR D-77-23).

4A11E Exploration for Sand to be Used for Dike Construction at Windmill Point. Soil and Material Engineers, Inc. $13,000. No report planned.

4A11F Technical and Administrative Support by Norfolk District for the Windmill Point Project. Norfolk District, CE. $59,546. Report incorporated in Internal Working Document.

4A11G Sediment and Water Chemistry Investigation at Windmill Point. Old Dominion University. $80,209. Combined with 4A11D and 4A11H.

4A11H Pollutant Mobilization Studies at Windmill Point. Old Dominion University. $105,872. Combined with 4A11D and 4A11G.

4A11I Ecological Studies at Windmill Point. Virginia Institute of Marine Science. $210,600. Report published as Appendix D to site report (TR D-77-23).

4A11J Propagation of Vascular Plants at Windmill Point. Environmental Concern, Inc. $49,556. Report published as Appendix B to site report (TR D-77-23).

4A11K Assessment of Acute Impacts on the Macrobenthic Community at Windmill Point. Virginia Institute of Marine Science. $31,939. Report published as Appendix C to site report (TR D-77-23).

4A11M Habitat Development Field Investigations, Windmill Point Marsh Development Site, James River, Virginia. Summary Report. EL, WES. Report published as TR D-77-23.

4A12 Buttermilk Sound, Marsh Habitat Development Site, Georgia.

4A12A Study of the Biological, Chemical, and Physical Changes Associated with Marsh Establishment on Sandy Dredged Material in Buttermilk Sound. University of Georgia. $407,169. Report published as Appendix A to site report (TR D-78-26).

4A12B Site Preparation, Propagule Collection, and Initial Steps in Planting Buttermilk Sound. University of Georgia. $8,262. No report planned.

4A13	Bolivar Peninsula Marsh and Upland Habitat Development Site, Galveston Bay, Texas.
4A13A	Topographic Survey of Bolivar Peninsula. Galveston District, CE. $7,000. Combined with 4A13B, G, and H. No report planned.
4A13B	Development of Soil Sampling and Testing Plans for Bolivar Peninsula. Galveston District, CE. $22,000. Combined with 4A13A, G, and H. No report planned.
4A13C	Inventory and Assessment of Hydrology and Water Chemistry at the Bolivar Peninsula Site. U. S. Geological Survey. $28,380. Report published as Appendix A to site report (TR D-78-15).
4A13D	Inventory and Assessment of the Aquatic Biota at Bolivar Peninsula. National Marine Fisheries Service. $62,656.Report published as Appendix C to site report (TR D-78-15).
4A13E	Inventory and Assessment of the Terrestrial Flora, Fauna, and Sediment Chemistry at Bolivar Peninsula. Texas A&M University. $51,823. Report published as Appendix B to site report (TR D-78-15).
4A13F	Propagation of Vascular Plants and Post-Propagation Monitoring of the Botanical, Soils, Aquatic Biota, and Wildlife Resources, Bolivar Peninsula. Dept. of Range Science, Texas A&M University. $408,083. Report published as Appendix D to site report (TR D-78-15).
4A13G	Plans and Specifications for Site Construction, Bolivar Peninsula. Galveston District, CE. $16,000. Combined with 4A13A, B, and H. No report planned.
4A13H	Sampling and Testing of Sediments, Bolivar Peninsula. Galveston District, CE. $6,000. No report planned.
4A13I, 4A13J	Construction, Maintenance, and Repair of Site, Bolivar Peninsula. Galveston District, CE. $288,000. No report planned.
4A13K	Habitat Development Field Investigations, Bolivar Peninsula Marsh and Upland Habitat Development Field Site, Bolivar Peninsula, Texas. Summary Report. EL, WES. Report published as TR D-78-15.

4A14	Rennie Island Marsh Habitat Development Site, Grays Harbor, Washington.
4A14A	Preliminary Survey, Rennie Island. Seattle District, CE. $23,000. No report planned.
4A14B	Preparation of Work Statements for Rennie Island. Coastal Ecosystem Management. $1,243. No report planned.
4A14C	Baseline Study and Literature Review. Fisheries Research Institute, University of Washington. $18,412. Report published as Appendixes A-C to site report (TR D-78-11).
4A14D	Habitat Development Field Investigations, Rennie Island Marsh Development Site, Grays Harbor, Washington. Summary Report. EL, WES. Report published as TR D-78-11.
4A16	Prediction of a Stable Elevation for a Marsh Developed from Dredged Material. Massachusetts Institute of Technology. $99,000. Report incorporated in Internal Working Document.
4A17	Dyke Marsh Demonstration Area, Feasibility Study. EL, WES. $30,000. Report published as TR D-76-6.
4A17A	Detailed Design—Dyke Marsh Demonstration Area, Virginia. EL, WES. $96,000. Report published as TR D-77-13.
4A18	Salt Pond #3 Marsh Habitat Demonstration Area, San Francisco, California. San Francisco District, CE. $50,350. No report planned.
4A18A	Post-Propagation Monitoring, Salt Pond #3 Marsh Development Site, San Francisco, California. San Francisco Bay Marine Research Center. $63,867. Data input for Work Unit 4A18B.
4A18B	Habitat Development Field Investigations, Salt Pond #3 Marsh Development Site, San Francisco Bay, California. Summary Report. EL, WES. Report published as TR D-78-57.

4A19	Apalachicola Marsh Development Site, Apalachicola, Florida. Mobile District, CE. $8,490. Report incorporated in Internal Working Document.
4A19A	Habitat Development Field Investigations, Apalachicola Bay Marsh Development Site, Apalachicola Bay, Florida. Summary Report. Environmental Systems Services at Tallahassee and EL, WES. Report published as TR D-78-32.
4A20	Productivity of Marsh Plants, Pacific Coast. Dr. R. W. Rountree. $11,800. Report incorporated in Internal Working Document.
4A21	Influence of Pregermination Conditions on the Viability of Selected Marsh Plants. Washington State University. $16,987. Report published as TR D-78-51.
4A22	Engineering Aspects of Habitat Development Project Field Sites—Synthesis Reports. EL, WES. $74,000. Reports published as TR DS-78-15, TR DS-78-17, and TR DS-78-19.
4A24	Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation—Synthesis Report. EL, WES. Report published as TR DS-78-16.
4A25	Recent and Planned Marsh Establishment Work Throughout the Contiguous United States—A Survey and Basic Guidelines. Environmental Concern, Inc. $9,609. Report published as CR D-77-3.
4A26	Field Testing of Rapid Bioassay Techniques for Marsh Development. University of Georgia. $9,850. Report published as MP D-78-6.
4B06	Establishment and Growth of Selected Fresh Water and Coastal Marsh Plants in Relation to the Characteristics of Dredged Sediments. EL, WES. $255,571. Report published as TR D-77-2.

REPORTS PUBLISHED. . . . .

CR D-74-9 **(Work Unit 4A03)**	Kadlec, J. A., Wentz, W. A., Jr., and Smith, R. L., "State-of-the-Art Survey and Evaluation of Marsh Plant Establishment Techniques: Induced and Natural (Volumes I and II)," December 1974, prepared by the School of Natural Resources, The University of Michigan-Ann Arbor, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A012 837.
CR D-75-2 **(Work Unit 4A08)**	Johnson, L. E., and McGuinness, W. V., Jr., "Guidelines for Material Placement in Marsh Creation," April 1975, prepared by the Center for Environment and Man, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD 010 725.
CR D-76-2 **(Work Unit 4A01)**	Coastal Zone Resources Corporation, "Identification of Relevant Criteria and Survey of Potential Application Sites for Artificial Habitat Creation (Volumes I and II)," October 1976, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A033 525.
TR D-76-6 **(Work Unit 4A17)**	Palermo, M. R., and Zeigler, T. W., "Feasibility Study for Dyke Marsh Demonstration Area, Potomac River, Virginia," November 1976, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A033 524.
MP D-77-1 **(Work Unit 4A09)**	Falco, P. K., and Cali, F. J., "Pregermination Requirements and Establishment Techniques for Salt Marsh Plants," September 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A045 514.
TR D-77-2 **(Work Unit 4B06)**	Barko, J. W., et al., "Establishment and Growth of Selected Freshwater and Coastal Marsh Plants in Relation to the Characteristics of Dredged Sediments," March 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A039 495.

CR D-77-3 (Work Unit 4A25)	Garbisch, E. W., Jr., Recent and Planned Marsh Establishment Work Throughout the Contiguous United States—A Survey and Basic Guidelines," April 1977, prepared by Environmental Concern, Inc., St. Michaels, Maryland, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A041 464.
TR D-77-13 (Work Unit 4A17A)	Palermo, M. R., and Zeigler, T. W., "Detailed Design for Dyke Marsh Demonstration Area, Potomac River, Virginia," October 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A048 179.
TR D-77-23	Habitat Development Field Investigations, Windmill Point Marsh Development Site, James River, Virginia.
Site Report	Lunz, J. D., et al., "Summary Report," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A066 224.
Appendix A (Work Unit 4A11C)	Silberhorn, G. M., and Barnard, T. A., Jr., "Assessment of Vegetation on Existing Dredged Material Islands," December 1978, prepared by the Virginia Institute of Marine Science under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix B (Work Unit 4A11J)	Garbisch, E. W., Jr., "Propagation of Vascular Plants," December 1978, prepared by Environmental Concern, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix C (Work Unit 4A11K)	Diaz, R. J., and Boesch, D. F., "Environmental Impacts of Marsh Development with Dredged Material: Acute Impacts on the Macrobenthic Community," November 1977, prepared by the Virginia Institute of Marine Science under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A055 319.

Appendix D (Work Unit 4A11I)	Virginia Institute of Marine Science, "Environmental Impacts of Marsh Development with Dredged Material: Botany, Soils, Aquatic Biology, and Wildlife," June 1978, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 842.
Appendix F (Work Unit 4A11D, G, and H)	Adams, D. D., Darby, D. A., and Young, R. J., "Environmental Impacts of Marsh Development with Dredged Material: Sediment and Water Quality. Volume I: Characteristics of Channel Sediments Before Dredging and Effluent Quality During and Shortly After Marsh Development. Volume II: Substrate and Chemical Flux Characteristics of a Dredged Material Marsh," August 1978, prepared by Old Dominion University Research Foundation under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS Nos. AD A061 917 and AD A062 841.
TR D-77-28 (Work Unit 4A04A2)	Gallagher, J. L., Plumley, F. G., and Wolf, P. L., "Underground Biomass Dynamics and Substrate Selective Properties of Atlantic Coastal Salt Marsh Plants," December 1977, prepared by University of Georgia Marine Institute under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A055 761.
TR D-77-35 (Work Unit 4A05)	Zieman, J. C., and Odum, W. E., "Modeling of Ecological Succession and Production in Estuarine Marshes," November 1977, prepared by Dept. of Environmental Sciences, University of Virginia, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A051 929.
TR D-77-36 (Work Unit 4A04A1)	Reimold, R. J., and Linthurst, R. A., "Primary Productivity of Minor Marsh Plants in Delaware, Georgia, and Maine," November 1977, prepared by Marine Extension Service, University of Georgia, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A051 164.
TR D-77-38	Habitat Development Field Investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon.

Site Report (Work Unit 4B05M)	Clairain, E. J., et al., "Summary Report," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
Appendix A (Work Unit 4B05E)	Cutshall, N., and Johnson, V. G., "Physical and Chemical Inventory," December 1978, prepared by the School of Oceanography, Oregon State University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix B (Work Unit 4B05C, J, and L)	McConnell, R. J., et al., "Inventory and Assessment of Predisposal and Postdisposal Aquatic Habitats," December 1978, prepared by the National Marine Fisheries Service under Interagency Agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix C (Work Unit 4B05D)	Woodward-Clyde Consultants, "Terrestrial Ecology Inventory," December 1978, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix D (Work Unit 4B05G)	Ternyik, W. E., "Propagation of Vascular Plants on Dredged Material," December 1978, prepared by the Wave Beach Grass Nursery under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix E (Work Unit 4B05K)	Heilman, P. E., et al., "Postpropagation Assessment of Botanical and Soil Resources on Dredged Material," August 1978, prepared by Washington State University at Pullman under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 261.
Appendix F (Work Unit 4B05I)	Crawford, J. A., and Edwards, D. K., "Postpropagation Assessment of Wildlife Resources on Dredged Material," May 1978, prepared by the Department of Fish and Wildlife, Oregon State University at Corvallis, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 823. Published on microfiche and inclosed in site report.

TR D-77-40 (Work Unit 4A06)	Gambrell, R. P., et al., "Trace and Toxic Metal Uptake by Marsh Plants as Affected by Eh, pH, and Salinity," December 1977, prepared by the Center for Wetland Resources, Louisiana State Unviersity, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 914.
TR D-77-44 (Work Unit 4A04B)	Gosselink, J. G., Hopkinson, C. S., Jr., and Parrondo, R. T., "Common Marsh Plant Species of the Gulf Coast Area, Volume 1: Productivity. Volume 2: Growth Dynamics," December 1977, prepared by Louisiana State University, Baton Rouge, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A052 094 (Volume I) and AD A052 095 (Volume II).
TR D-78-11 (Work Unit 4A14D)	Vincent, M. K., "Habitat Development Field Investigations, Rennie Island Marsh Development Site, Grays Harbor, Washington; Summary Report," April 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 909.
TR D-78-15	Habitat Development Field Investigations, Bolivar Peninsula, Marsh and Upland Habitat Development Site, Galveston Bay, Texas.
Site Report (Work Unit 4A13K)	Allen, J. H., et al., "Summary Report," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 780.
Appendix A (Work Unit 4A13C)	U. S. Geological Survey and Lunz, J. D., et al., "Baseline Inventory of Water Quality, Sediment Quality, and Hydrodynamics," August 1978, performed under an Interagency Agreement and by the Environmental Laboratroy, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix B (Work Unit 4A13E)	Dodd, J. D., et al., "Baseline Inventory of Terrestrial Flora, Fauna, and Sediment Chemistry," August 1978, prepared by the College of Agriculture, Texas A&M University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.

Appendix C (Work Unit 4A13D)	Lyon, J. M., and Baxter, K. N., "Inventory and Assessment of Aquatic Biota," August 1978, prepared by National Marine Fisheries Service under an Interagency Agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix D (Work Unit 4A13F)	Webb, J. W., et al., "Propagation of Vascular Plants and Postpropagation Monitoring of Botanical, Soil, Aquatic Biota, and Wildlife Resources," June 1978, prepared by Texas Agricultural Experiment Station, Texas A&M University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 781.
TR D-78-26	Habitat Development Field Investigations, Buttermilk Sound Marsh Development Site, Atlantic Intracoastal Waterway, Georgia.
Site Report (Work Unit 4A12A)	Cole, R. A., "Summary Report," July 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A057 937.
Appendix A (Work Unit 4A12A)	Reimold, R. J., et al., "Propagation of Marsh Plants and Postpropagation Monitoring," July 1978, prepared by the Marine Extension Service, University of Georgia, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 867.
TR D-78-31 (Work Unit 4A07A)	Eckert, J. W., et al., "Design Concepts for In-Water Structures for Marsh Habitat Development," July 1978, prepared by the U. S. Army Coastal Engineering Research Center for the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 732.
TR D-78-32 (Work Unit 4A19A)	Kruczynski, W. L., Huffman, R. T., and Vincent, M. K., "Habitat Field Investigations, Apalachicola Bay Marsh Development Site, Apalachicola Bay, Florida," August 1978, prepared by Environmental Systems Service of Tallahassee, Inc., and Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 722.

TR D-78-51
(Work Unit 4A21)

Maguire, J. D., and Heuterman, G. A., "Influence of Pregermination Conditions on the Viability of Selected Marsh Plants," August 1978, prepared by Seed Technology Laboratory, Washington State University, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 629.

TR D-78-57

Morris, J. H., et al., "Habitat Development Field Investigations, Salt Pond No. 3 Marsh Development Site, South San Francisco Bay, California," December 1978, San Francisco Bay Marine Research Center and Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A065 775.

MP D-78-6
(Work Unit 4A26)

Wolf, P. L., Gallagher, J. L., and Pennington, C. H., "Field Bioassay Test for Detecting Contaminant Uptake from Dredged Material by Marsh Plants," December 1978, prepared by the University of Georgia under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A066 802.

TR D-78-15
(Work Unit 4A22)

Lunz, J. D., Diaz, R. J., and Cole, R. A., "Upland and Wetland Habitat Development with Dredged Material: Ecological Considerations," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 780.

TR D-78-19
(Work Unit 4A22)

Smith, H. K., "An Introduction to Habitat Development with Dredged Material," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 841.

TR DS-78-16
(Work Unit 4A24)

Huffman, R. T., et al., "Wetland Habitat Development with Dredged Material: Engineering and Plant Propagation," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 371.

TERRESTRIAL HABITAT DEVELOPMENT

(Task 4B: Habitat Development Project)

OBJECTIVE. . . . .

—to develop and apply habitat management methodologies to upland disposal areas for purposes of habitat development, reclamation, and mitigation—

APPROACH. . . . .

—document natural plant succession patterns at terrestrial disposal areas, establish field sites to demonstrate the concept of reclamation of dredged material for upland habitat development; test plant species that both attract wildlife and thrive in disposal areas—

IMPLEMENTATION. . . . .

—10 work units (in-house efforts, contracts, interagency agreements) involving a total expenditure of $1,121,087.

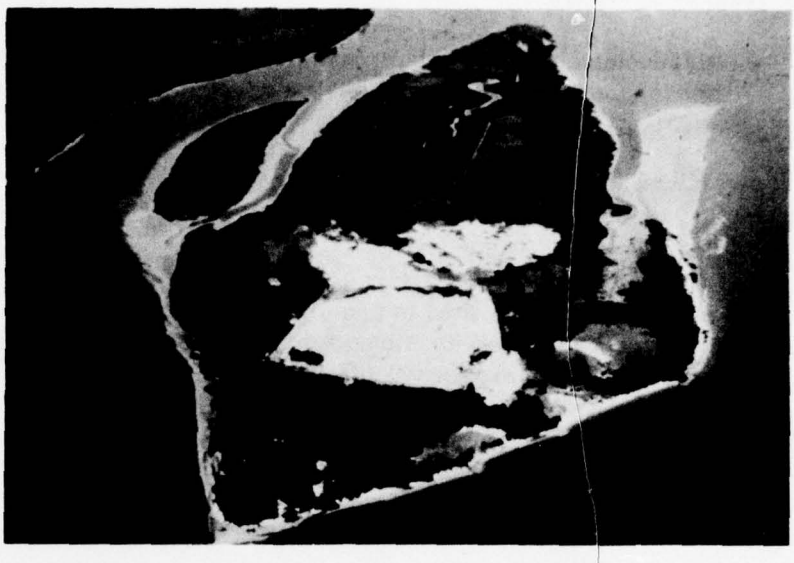
—final results published in 5 Technical Reports (including 3 field site reports with 13 appendixes), 1 Miscellaneous Paper, and 1 Synthesis Report.

RESULTS. . . . .

Field Sites—

Terrestrial habitat was successfully established at upland dredged material disposal sites in Connecticut, Texas, and Oregon. Various propagation and management techniques such as fertilization, selection of drought-tolerant species, and animal control were applied. Two of these sites (Texas and Oregon) include marsh development and those aspects are discussed under Task 4A. (See page 107.)

NOTT ISLAND. Nott Island in the Connecticut River, Connecticut, was the location of the reclamation for wildlife purposes of an 8-acre disposal site. About 23,000 cu yd of sandy material from the navigation channel of the river was disposed at this site in 1975. To improve agronomic characteristics, the area was top dressed with 11,500 cu yd of fine-grained material and the two substrates were subsequently mixed. The area was limed and fertilized and planted with a mixture of grasses and legumes to provide a feeding area for Canada geese. *Festuca elatior* grew well and a number of grasses, primarily *Panicum spp.*, invaded the area. High soil salinity and some nutrient deficiencies proved detrimental to legumes. White-tailed deer and Canada geese grazed the site heavily. (See TR D-78-25.)



BOLIVAR PENINSULA. Reclamation of a droughty upland disposal site was incorporated into marsh studies on the Bolivar Peninsula near Galveston, Texas. Research centered around evaluation of the success of several desirable wildlife plant species under a series of fertilizer regimes. The objective of this research was the identification of trees, shrubs, and grasses that are adaptable to this and similar sites along the Gulf Coast. *Cynodon dactylon, Panicum amarum,* and *Quercus virginiana* had the greatest rate of survival. Invasion by other plant species in the areas planted to trees and shrubs was significant, probably because of the fertilization. (See TR D-78-15.)

MILLER SANDS. A 45-acre portion of an island in the Lower Columbia River that developed as a result of long-term dredged material disposal was the location of upland habitat development. Fertilization and test plantings of nine wildlife food-plant species were conducted to test legume and grass combinations and to improve the site for wildlife. Waterfowl response included nesting by mallards and grazing by Canada and snow geese. Although vegetation was established successfully, additional fertilization applications and seedings would probably be necessary to maintain this desirable vegetative cover. (See TR D-77-38.)

Habitat Development Advances—

—specific situations in which wildlife habitat has been established naturally were examined; concepts useful for planning such establishment were derived. (See Work Unit 4B01.)

—techniques for disposal of dredged material that are compatible with habitat development were identified, including considerations of equipment, disposal area size and configuration, and use of dredged material to direct vegetation succession. (See MP D-77-5.)

—upland disposal site vegetation succession patterns at five sites (Connecticut, Florida, Louisiana, Texas, and Oregon) supply background for management decisions. (See CR D-77-2.) Succession information was also derived from research under Task 4F (see page 147).

—control of *Phragmites australis*, the common reed, is of concern in many parts of the country. Work Unit 4B07 was a literature review of chemical, mechanical, and biological control techniques.

—a list of 250 plant species with food and cover value for wildlife was derived under Work Unit 4B08; 100 of these were selected for their importance to wildlife, ease of establishment on dredged material, and representative geographic distribution and were discussed in synopsis form. The product is a user-oriented handbook for terrestrial habitat development. (See TR D-78-37.)

A Synthesis—

The successful conduct of a habitat development project associated with dredging and disposal operations is dependent on basic engineering, agronomic, and ecological principles and on well-coordinated planning activities. Guidelines for planning, constructing, and maintaining upland habitats were derived from field site results, published literature, and other sources. (See TR DS-78-17.)

WORK UNITS. . . . .

4B01	Identification and Assessment of Modes, Needs, Benefits, and Constraints of Habitat Enhancement. Hittman Associates. $83,854. Results incorporated into Internal Working Document.
4B04	Nott Island Upland Habitat Development Site, Connecticut River, Connecticut.
4B04A	Preoperational Data Collection and Monitoring of Dredged Material Disposal, Nott Island. Marine Sciences Institute. University of Connecticut. $25,135. Published as Appendix A to site report (TR D-78-25).
4B04B	Technical Liaison, Nott Island. Connecticut Department of Environmental Protection. $1,900. No report planned.
4B04C	Growth of Selected Plant Species on Dredged Material. Cooperative Extension Service, University of Connecticut. $75. Results incorporated into Internal Working Document.
4B04D	Experimental Control of *Phragmites australis*. Connecticut College. $4,750. Results incorporated into Internal Working Document.

4B04E Monitoring of Dredged Material Disposal and Reclamation, Nott Island. Connecticut College. $34,367. Published as Appendix B to site report (TR D-78-25).

4B04F Postpropagation Monitoring of Flora and Fauna at Nott Island. Connecticut College. $36,680. Published as Appendix C to site report (TR D-78-25).

4B04G Habitat Development Field Investigations, Nott Island Upland Habitat Development Site, Connecticut River, Connecticut. Summary Report EL, WES. Published as TR D-78-25.

4B05 Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon.

4B05A Subsurface Exploration, Miller Sands. Portland District, CE. $6,000. No report planned.

4B05B Preparation of Work Statements, Miller Sands. Coastal Ecosystems Management. $1,243. No report planned.

4B05C Baseline Biological Inventory and Assessment of the Aquatic Environs of Miller Sands. National Marine Fisheries Service. $38,500. Combined with Work Units 4B05J and 4B05L. Report published as Appendix B to site report (TR D-77-38).

4B05D Inventory and Assessment of Prepropagation Terrestrial Resources on Dredged Material. Woodward-Clyde Consultants. $38,926. Report published as Appendix C to site report (TR D-77-38).

4B05E Inventory and Assessment of Predisposal Physical and Chemical Conditions. Oregon State University. $52,689. Report published as Appendix A to site report (TR D-77-38).

4B05F Pilot Study of Propagation of Marsh Plants at Miller Sands. Wave Beach Grass Nursery. $9,817. Results incorporated into Internal Working Document.

4B05G Propagation of Vascular Plants on Dredged Material in Wetland and Upland Habitats. Wave Beach Grass Nursery. $87,912. Report published as Appendix D to site report (TR D-77-38).

4B05H Trapping of Nutria at Miller Sands. Jack Rogers. $34,160. No report planned.

4B05I	Postpropagation Assessment of Wildlife Resources on Dredged Material. Oregon State University. $39,855. Report published as Appendix F to site report (TR D-77-38).
4B05J	Aquatic Biology Investigations at Miller Sands. National Marine Fisheries Service. $80,000. Combined with Work Units 4B05C and 4B05L.
4B05K	Postpropagation Assessment of Botanical and Soil Resources on Dredged Material. Washington State University. $167,798. Report published as Appendix E to site report (TR D-77-38).
4B05L	Postoperational Aquatic Biology at Miller Sands. National Marine Fisheries Service. $46,072. Combined with Work Units 4B05C and 4B05J.
4B05M	Habitat Development Field Investigations, Miller Sands Marsh and Upland Habitat Development Site, Columbia River, Oregon. Summary Report EL, WES. Report published as TR D-77-38.
4B07	The Biology and Control of the Common Reed *Phragmites australis*. Louisiana Technological Institute. $1,750. Results incorporated into Internal Working Document.
4B08	Plant Selection for Wildlife Habitat Development on Dredged Material. Coastal Zone Resources. $38,312. Report published as TR D-78-37.
4B09	Upland Habitat Development with Dredged Material: Engineering and Plant Propagation–A Synthesis Report. EL, WES. Report published as TR DS-78-17.
5B01	Regional Identification of Species Affected by Dredging/-Disposal Operations. MESL, WES. $43,700. Results incorporated into Internal Working Document.
5B02	Assessment of Species Habitat Requirements and Responses of Populations to Habitat Conditions. MESL, WES. $59,000. No report planned.
5B03	Study of Successional Patterns of Plants and Animals at Upland Disposal Areas. Coastal Zone Resources Corporation. $101,887. Report published as CR D-77-2.
5B04	Review of Dredged Material Disposal Techniques to Identify Wildlife Habitat Development Factors. Dames and Moore. $87,014. Report published as MP D-77-5.

REPORTS PUBLISHED. . . . .

CR D-77-2 (Work Unit 5B03)	Coastal Zone Resources Corporation, "A Comprehensive Study of Successional Patterns of Plants and Animals at Upland Disposal Areas," March 1977, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A040 464.
MP D-77-5 (Work Unit 5B04)	Dames and Moore, "Review of Dredged Material Disposal Techniques to Identify Wildlife Habitat Development Factors," December 1977, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 441.
TR D-78-25	Habitat Development Field Investigations, Nott Island Upland Habitat Development Site, Connecticut River, Connecticut
Site Report (Work Unit 4B04G)	Hunt, L. J., et al., "Summary Report," August 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 725.
Appendix A (Work Unit 4B04A)	Warren, R. S., and Niering, W. A., "Preliminary Terrestrial Ecological Survey," August 1978, prepared by Connecticut College under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix B (Work Unit 4B04E)	Warren, R. S., Niering, W. A., and Barry, W. J., "Survey of Terrestrial Ecology and Preliminary Botanical Monitoring," August 1978, prepared by Connecticut College under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. Published on microfiche and inclosed in site report.
Appendix C (Work Unit 4B04C)	Barry, W. J., et al., "Postpropagation Monitoring of Vegetation and Wildlife," August 1978, prepared by Connecticut College under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

TR D-78-37
(Work Unit 4808)

Coastal Zone Resources Division, "Handbook for Terrestrial Wildlife Habitat Development on Dredged Material," July 1978, prepared by Ocean Data Systems, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 114.

TR DS-78-17
(Work Unit 4809)

Hunt, L. J., et al., "Upland Habitat Development with Dredged Material: Engineering and Plant Propagation," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

AQUATIC HABITAT DEVELOPMENT

(Task 4E: Habitat Development Project)

OBJECTIVE. . . . .

—to evaluate and test the feasibility of using dredged material as a substrate for aquatic habitat development and determine the impact of disposal of dredged material on aquatic habitats—

APPROACH. . . . .

—a literature survey of pertinent information and a small field test to determine the feasibility of using dredged material as a substrate for aquatic habitat development—

IMPLEMENTATION. . . . .

—2 work units (contracted) involving a total expenditure of $37,093.

—final results published in 2 technical reports.

RESULTS. . . . .

Literature Survey of Seagrasses—

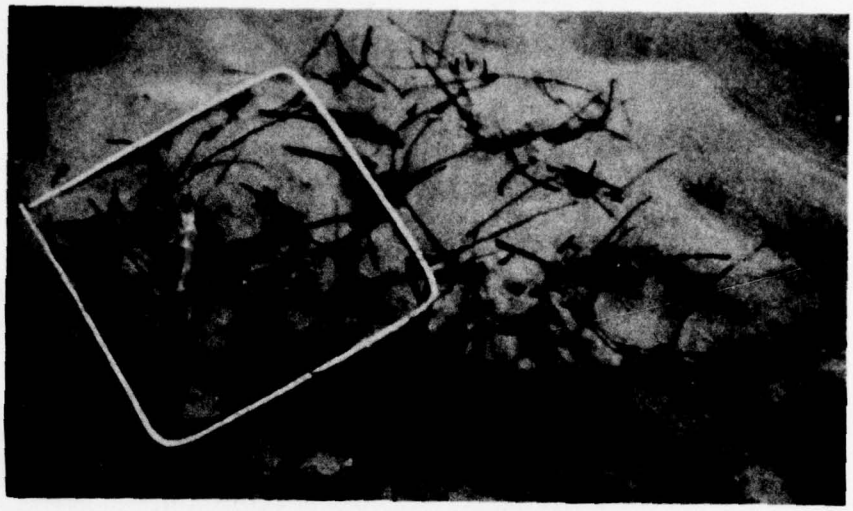
Pertinent literature on seagrasses was compiled from both published and unpublished sources. Broad subject areas that relate to seagrasses such as anatomy, ecology, morphology, taxonomy, and physiology were considered together with more specific factors such as substrate, water quality, productivity, colonization, effect of physical energy (waves, tidal currents, sediment transport), propagation, impact of dredging, and tolerance to disturbance. (See TR D-78-4.)

Grassbed Development—

During August 1976 shoalgrass *(Halodule beaudetti)* was transplanted from a natural grassbed to a nearby dredged material disposal site that is adjacent to the Gulf County Canal, Port St. Joe, Florida. The substrate consisted of sandy material. Initial site monitoring revealed a high rate of survival and spread; however, gradual decline in survival was evident throughout further monitoring periods. Latest monitoring reveals that no seagrass transplants are visible. It is presumed that much of the decrease was due to an extremely cold winter (coldest on record) and/or effluent from nearby industries. (See TR D-78-33.)

Shoalgrass (*Halodule beaudetti*) transplants were obtained at a natural seagrass bed near Port St. Joe, Florida, placed in water-filled containers, and immediately transported to and planted at a nearby dredged material disposal site.

Seagrass transplanting operation on dredged material near Port St. Joe, Florida. In the absence of mechanical techniques, seagrass transplantation is now a labor-intensive effort.



Shoalgrass (*Halodule beaudetti*) 10 months after transplantation. The initial transplant consisted of a plug 28 in. square. The size of the square in the photo is 16 in. square.

WORK UNITS. . . . .

4E01	Literature Survey of Seagrasses. University of Virginia. $28,963. Report published as TR D-78-4.
4E02	Grassbed Development, St. Joseph Bay, Florida. Dr. R. C. Phillips. $8,130. Report published as TR D-78-33.

REPORTS PUBLISHED. . . . .

TR D-78-4 (Work Unit 4E01)	Bridges, K. W., Zieman, J. C., and McRay, C. P., "Seagrass Literature Survey," January 1978, prepared by the Department of Environmental Sciences, University of Virginia, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A054 480.
TR D-78-33 (Work Unit 4E02)	Phillips, R. C., Vincent, M. K., and Huffman, R. T., "Habitat Development Field Investigations, Port St. Joe, Florida; Summary Report," July 1978, Seattle Pacific College and Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 733.

ISLAND HABITAT DEVELOPMENT

(Task 4F: Habitat Development Project)

OBJECTIVE. . . . .

—investigate, evaluate, and test methodologies for habitat creation and management on dredged material islands—

APPROACH. . . . .

—document vegetative succession on dredged material islands and determine the use of those islands by wildlife in seven representative coastal and riverine areas of the United States—

IMPLEMENTATION. . . . .

—10 work units (4 in-house efforts, 6 contracts) involving a total expenditure of $463,414.

—final results published in 11 reports, including 1 Synthesis Report.

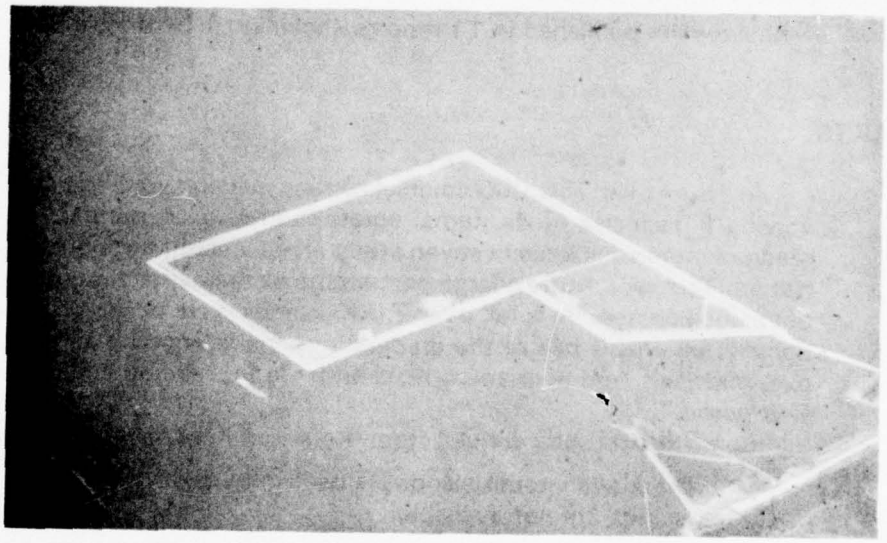
RESULTS. . . . .

In 1977 over 750,000 colonial nesting sea and wading birds involving 31 species (gulls, terns, egrets, heron, pelicans, etc.) used dredged material islands in seven study areas located throughout the Nation. This represents a large percentage of the national population of colonial nesters. In total, over 2,000 islands were observed. Additionally, extensive use of the dredged material islands by migratory, overwintering, and permanent resident birds for feeding and nesting was noted.

Some conclusions derived from the seven regional studies are:

- Dredged material islands are used extensively where natural islands are not available.
- Dredged material islands are actually preferred nesting sites in some regions, even though natural sites are avialable.
- Some dredged material islands are not suitable as nesting habitats due to factors such as human disturbance, configuration, elevation, predation, location, and vegetation.
- Vegetation determines bird species using an island, and vegetation succession rates and patterns determine the duration of use by a particular species.

- The construction of permanent dikes to contain material placed on islands affected the habitat of those islands in several ways. In some instances the habitat benefited through increased diversity and attraction of additional species. In most cases diking substantially altered vegetative succession and thus the species composition of colonial nesting birds was altered.
- In all regions, human disturbance and intrusion were found to be highly detrimental to the establishment and success of bird colonies.



Isolated disposal sites in the Great Lakes, such as this site near Toledo, Ohio, receive heavy colonial bird use. This indicates considerable potential for the development of important habitats on otherwise biologically unproductive areas.

Bird Island, formed in 1963 by dredged material disposal, is heavily used by colonial bird species in Tampa Bay, Florida.

A diked dredged material island in North Carolina. Diked and undiked islands have markedly different vegetation successional patterns, a fact which greatly affects colony site selection by birds. Many species benefit from the feeding areas which form in the borrow pits behind the dike.

WORK UNITS. . . . .

4F01A	Survey of Critical Nesting and Migration Areas of the Great Lakes and Comparisons of Dredged Material and Natural Island Breeding Habitats. Northwest Michigan College. $57,432. Completed: Report published as TR D-78-10.
4F01B	Use of Dredged Material Islands by Colonial Seabirds and Wading Birds in Texas. Texas A&I University. $85,113. Report published as TR D-78-8.
4F01C	Use of Dredged Material Islands by Colonial Seabirds and Wading Birds in Florida. Seabird Research, Inc. $61,830. Report published as TR D-78-14, Volumes I and II.
4F01D	Use of Dredged Material Islands by Colonial Seabirds and Wading Birds in New Jersey. Manomet Bird Observatory. $98,983. Report published as TR D-78-1.
4F01E	Use of Dredged Material Islands by Colonial Nesting Seabirds and Wading Birds in the Pacific Northwest. John Graham Company. $47,715. Report published as TR D-78-17.
4F01F	Use of Dredged Material Islands by Colonial Seabirds and Wading Birds (Upper Mississippi River). EL, WES. $17,619. Report published as TR D-78-13.
4F02	A Comparison of Plant Succession and Bird Utilization on Diked and Undiked Dredged Material Islands in North Carolina Estuaries. University of North Carolina. $94,721. Report published as TR D-78-9.
4F03	Development and Management of Avian Habitat on Dredged Material Islands–A Synthesis Report. EL, WES. Report published as TR DS-78-18.
4F04	A Selected Bibliography of the Life Requirements of Colonial Nesting Waterbirds and Their Relationship to Dredged Material Islands. EL, WES. Report published as MP D-78-5.
4F05	Annotated Tables of Vegetation Growing on Dredged Material Throughout the United Sates. EL, WES. Report published as MP D-78-7.

REPORTS PUBLISHED. . . . .

TR D-78-1 (Work Unit 4F01D)	Buckley, F. G., and McCaffrey, C. A., "Use of Dredged Material Islands by Colonial Seabirds and Wading Birds in New Jersey," June 1978, prepared by Manomet Bird Observatory under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 843.
TR D-78-8 (Work Unit 4F01B)	Chaney, A. H., et al., "Use of Dredged Material Islands by Colonial Seabirds and Wading Birds in Texas," April 1978, prepared by Texas A&I University at Kingsville under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 785.
TR D-78-9 (Work Unit 4F02)	Parnell, J. F., et al., "A Comparison of Plant Succession and Bird Utilization of Diked and Undiked Dredged Material Islands in North Carolina Estuaries," May 1978, prepared by the Department of Biology, University of North Carolina at Wilmington, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 000.
TR D-78-10 (Work Unit 4F01A)	Scharf, W. C., et al., "Colonial Birds Nesting on Man-Made and Natural Sites in the U. S. Great Lakes," May 1978, prepared by the Northwestern Michigan College at Traverse City under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 818.
TR D-78-13 (Work Unit 4F01F)	Thompson, D. H., and Landin, M. C., "An Aerial Survey of Waterbird Colonies Along the Upper Mississippi River and Their Relationship to Dredged Material Deposits," April 1978, prepared by Seabird Research, Inc., and the Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 059.
TR D-78-14 (Work Unit 4F01C)	"Colonial Bird Use and Plant Succession on Dredged Material Islands in Florida," April 1978, prepared by Seabird Research, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
Volume I	Schreiber, R. W., and Schreiber, E. A., "Sea and Wading Bird Colonies." NTIS No. AD A056 086.
Volume II	Lewis, R. R., and Lewis, C. S., "Patterns of Plant Succession." NTIS No. AD A056 803.

TR D-78-17
(Work Unit 4F01E)

Peters, C. F., et al., "Colonial Nesting Sea and Wading Bird Use of Estuarine Islands in the Pacific Northwest," May 1978, prepared by John Graham Company under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 926.

MP D-78-5
(Work Unit 4F04)

Landin, M. C., "A Selected Bibliography of the Life Requirements of Colonial Nesting Waterbirds and Their Relationship to Dredged Material Islands," September 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 643.

MP D-78-7
(Work Unit 4F05)

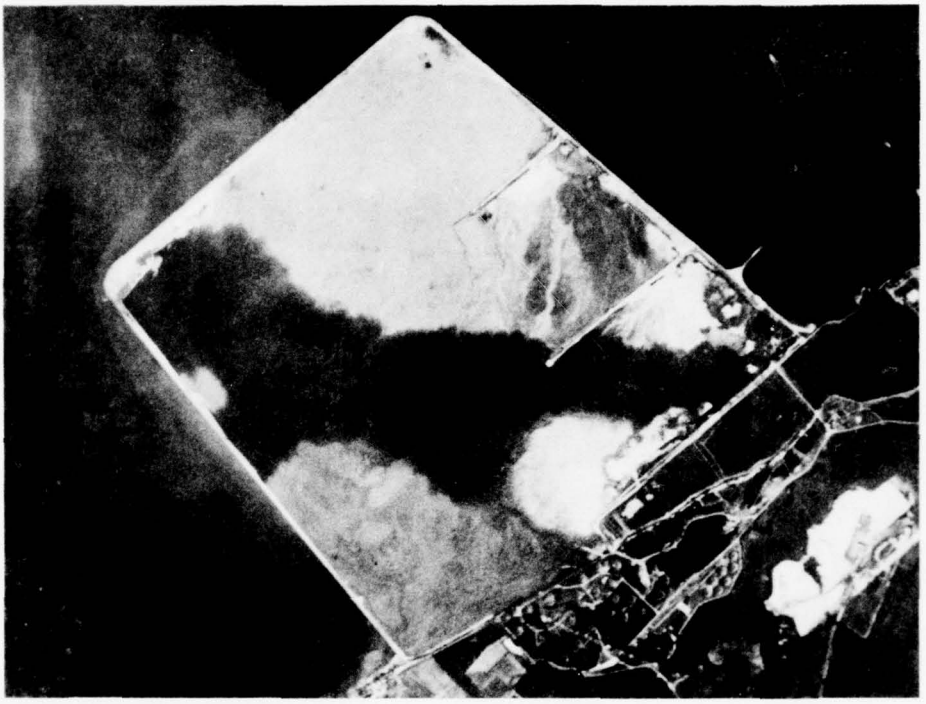
Landin, M. C., "Annotated Tables of Vegetation Growing on Dredged Material Throughout the U. S.," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A068 459.

TR DS-78-18

Soots, R. F., Jr., and Landin, M. C., "Development and Management of Avian Habitat on Dredged Material Islands," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A066 802.

CONTAINMENT AREA OPERATIONS

(Task 2C: Disposal Operations Project)



OBJECTIVE. . . . .

—to develop new or improved methods for the operation and management of confined disposal areas and associated facilities—

APPROACH. . . . .

—to develop and test concepts to facilitate area operations, prepare guidelines for area design and construction, demonstrate management practices to enhance area effectiveness and environmental compatibility—

IMPLEMENTATION. . . . .

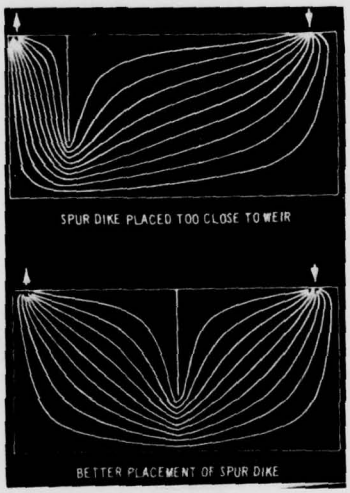
—20 work units (9 in-house efforts, 10 contracts, 1 interagency agreement) involving a total expenditure of $1,103,579.

—final results published in 14 in-house or contractor-prepared technical reports, 1 information transfer brochure, and 2 Synthesis Reports.

RESULTS. . . . .

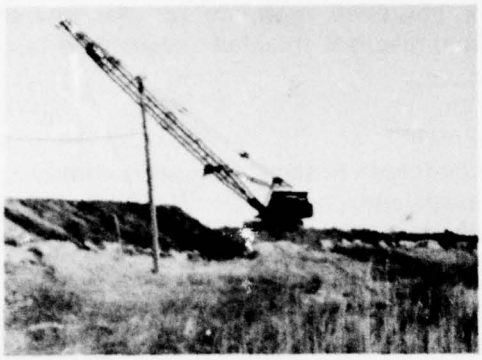
Containment Area Sizing—

Methodologies were developed to permit the sizing of containment areas for both effluent water quality and storage volume. Theoretical relationships were developed for short-term containment area sizing and for predicting the storage volume available for multiyear disposal operations as the dredged material undergoes sedimentation and self-weight consolidation. (See Work Unit 2C18 and Synthesis Report DS-78-10.)



The effects of various weir designs and spur dike configurations on effluent quality were investigated and guidelines for improving containment area efficiencies were developed. (See Work Unit 2C16, TR D-78-12, and Synthesis Report DS-78-10.)

Retaining Dike –

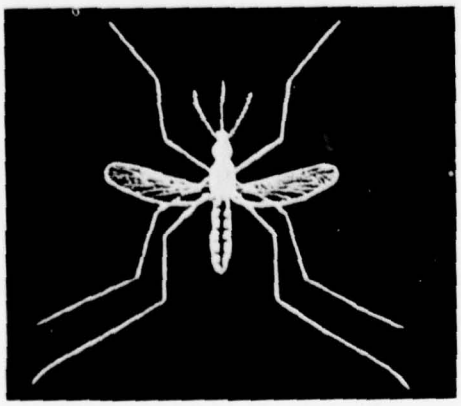


Guidelines for proper investigation, design, and construction of retaining dikes were developed to facilitate construction of adequate dikes even when poor materials and foundation conditions exist at a site. (See Technical Report D-77-9.)

Construction Equipment –

Various pieces of equipment suited for use in construction, maintenance, and management of dredged material containment areas were identified and evaluated. The type of work possible and areas of most productive use are identified in a Synthesis Report. (See Technical Reports D-77-1 and D-77-7 and Synthesis Report DS-78-9.)

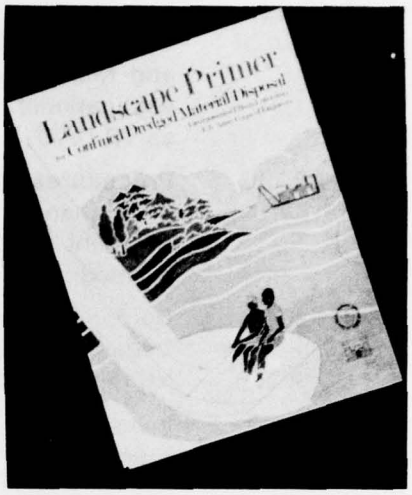
Mosquitos –



Significant advancement has been made in identification of specific locations and conditions conducive to mosquito propagation. Guidelines for management of disposal areas to control mosquito infestation were developed. (See TR D-78-48.)

Landscaping—

The aesthetics of confined disposal areas can be enhanced through the use of landscaping techniques that can be incorporated into development of specific sites. A public information brochure was published to help disseminate this information. (See CR D-75-5 and Work Unit 2C17.)



WORK UNITS. . . . .

2C02 Study of the Feasibility of the Functional Use of Vegetation for Slurry Filtering, Pollutant Constituent Removal, and Dredged Material Desiccation. EL, WES. $52,330. Report published as TR D-76-4.

2C03 Problems and Practices in Current Disposal Methods. SPL, WES. $55,387. Report published as TR D-74-2.

2C04 Development of Design and Construction Guidelines for Dredged Material Retaining Dikes. Savannah District, CE. $66,404. Report published as TR D-77-9.

2C05 Analysis of Functional Capabilities and Performance of Pervious Dikes, Sandfill Weirs, and Related Effluent Filtering Systems. Department of Civil Engineering, Northwestern University. $86,786. Report published as CR D-76-8.

2C06 Identification of Nature and Distribution of Objectionable Environmental Conditions in Confined Disposal Areas. Arthur D. Little, Inc. $34,990. Report published as CR D-74-4.

2C08 Development of Guidelines for Containment Facility Design. Interlaboratory team, WES. $65,015. Report published as TR D-76-1.

2C09A Development of Concepts Using Low-Ground-Pressure Construction Equipment for Containment Area Operation and Maintenance (Equipment Inventory). MESL, WES. $24,600. Report published as TR D-77-1.

2C09B Development of Concepts Using Low-Ground-Pressure Construction Equipment for Containment Area Operation and Maintenance (Development of Field Evaluation Investigations). MESL, WES. $88,400. Report published as TR D-77-7.

2C09C Procedures and Practices Used in Construction, Maintenance, and Management of Dredged Material Containment Areas. MESL, WES. $70,000. Findings incorporated into Synthesis Report DS-78-9.

2C10 Demonstration of Dredged Material Drying by Use of Vegetation. Biological Water Purification, Inc. $27,500. No report published.

2C11 Investigation of Physical, Chemical, and/or Biological Treatment for Odor Control in Dredged Material Disposal Areas. Argonne National Laboratory. $67,120. Report published as CR D-76-9.

2C12 Investigation of Physical, Chemical, and/or Biological Control of Mosquitoes in Dredged Material Disposal Areas. The Citadel. $71,845. Report published as TR D-78-48.

2C14 European Dredging and Disposl Practices. Adriaan Volker Dredging Company. $83,800. Report published as TR D-78-58.

2C15 Field Investigation of the Functional Use of Vegetation to Filter and Remove Contaminants from Existing Dredged Material Disposal Areas. EL, WES. $25,000. Final results incorporated with Work Unit 2D01.

2C16 Containment Area Design to Maximize Effectiveness of Confined Disposal Areas. Brian J. Gallagher and Co. $78,937. Final report published as TR D-78-12.

2C17 Public Information Brochure Regarding Land Planning Principles and Landscape Design Concepts for Confined Dredged Material Disposal Facilities. Roy Mann Associates. $16,276. Brochure published.

2C18 Guidelines for Sizing, Operation, and Management of Dredged Material Containment Areas. EL, WES. $43,000. Report published as TR DS-78-10.

2C19 Weir Design to Maintain Effluent Quality from Dredged Material Containment Areas. EL, WES. $2,400. Report published as TR DS-78-9.

4A16A Performance of Containment Areas Filled with Dredged Material. Massachusetts Institute of Technology. $99,500. Report published as TR D-77-21.

5E01 Landscaping Concept Development for Confined Dredged Material Disposal Sites. Roy Mann Associates. $44,289. Report published as CR D-75-5.

REPORTS PUBLISHED. . . . .

TR D-74-2 (Work Unit 2C03) Murphy, W. L., and Zeigler, T. W., "Practices and Problems in the Confinement of Dredged Material in Corps of Engineers Projects," May 1974, Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD 780 753.

CR D-74-4 (Work Unit 2C06) Harrison, J. E., and Chisholm, L. C., "Identification of Objectionable Environmental Conditions and Issues Associated with Confined Disposal Areas," September 1974, prepared by Arthur D. Little, Inc., Cambridge, Massachusetts, under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AS A000 895.

CR D-75-5 (Work Unit 5E01) Mann, R., et al., "Landscape Concept Development for Confined Dredged Material Sites," December 1975, prepared by Roy Mann Associates, Inc., Cambridge, Massachusetts, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD 026 684.

TR D-76-1 (Work Unit 2C08) Johnson, L. D., "Mathematical Model for Predicting the Consolidation of Dredged Material in Confined Disposal Areas," February 1976, Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A020 949.

TR D-76-4 (Work Unit 2C02) Lee, C. R., et al., "Feasibility of the Functional Use of Vegetation to Filter, Dewater, and Remove Contaminants from Dredged Material," June 1976, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A028 336.

CR D-76-8
(Work Unit 2C05)
Krizek, R. J., Fitzpatrick, J. A., and Atmatzidis, D. K., "Investigation of Effluent Filtering Systems for Dredged Material Containment Facilities," August 1976, prepared by the Department of Civil Engineering, Northwestern University, Evanston, Illinois, under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A031 368.

CR D-76-9
(Work Unit 2C11)
Harrison, W., et al., "Abatement of Malodors at Confined Dredged Material Disposal Sites," August 1976, prepared by Argonne National Laboratory, Argonne, Illinois, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A030 597.

TR D-77-1
(Work Unit 2C09A)
Green, C. E., and Rula, A. A., "Low-Ground-Pressure Construction Equipment for Use in Dredged Material Containment Area Operation and Maintenance:Equipment Inventory," April 1977, Mobility and Environmental Systems Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A041 451.

TR D-77-7
(Work Unit 2C09B)
Willoughby, W. E., "Low-Ground-Pressure Construction Equipment for Use in Dredged Material Containment Area Operation and Maintenance: Peformance Predictions," August 1977, Mobility and Environmenal Systems Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A044 209.

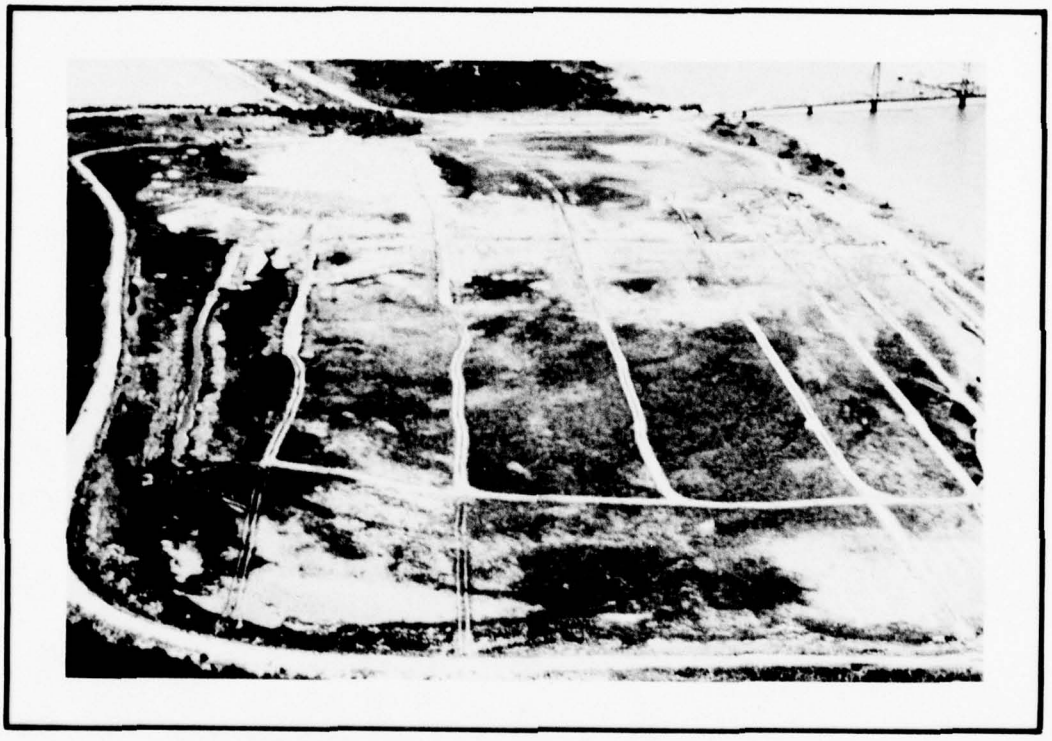
TR D-77-9
(Work Unit 2C04)
Hammer, D. P., and Blackburn, E. D., "Design and Construction of Retaining Dikes for Containment of Dredged Material," August 1977, U. S. Army Engineer District, Savannah, Soil Section, Savannah, Georgia. NTIS No. AD A045 311.

TR D-77-21
(Work Unit 4A16A)
Lacasse, S. E., Lambe, T. W., and Marr, W. A., "Sizing of Containment Areas for Dredged Material," October 1977, prepared by Massachusetts Institute of Technology under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 038.

TR D-78-12 (Work Unit 2C16)	Brian J. Gallagher and Company, "Investigation of Containment Area Design to Maximize Hydraulic Efficiency," May 1978, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A056 525.
TR D-78-48 (Work Unit 2C12)	Ezell, Wm. Bruce, Jr., ed., "An Investigation of Physical, Chemical, and/or Biological Control of Mosquitoes in Dredged Material Disposal Areas," August 1978, prepared by The Citadel, The Military College of South Carolina at Charleston, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 311.
TR D-78-58 (Work Unit 2C14)	d'Angremond, K., et al., "Assessment of Certain European Dredging Practices and Dredged Material Containment and Reclamation Methods," December 1978, prepared by Adriaan Volker under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
TR DS-78-9 (Work Unit 2C19)	*Willoughby, W. E., "Assessment of Low-Ground-Pressure Equipment in Dredged Material Containment Area Operations and Maintenance," December 1978, Mobility and Environmental Systems Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 501.*
TR DS-78-10 (Work Unit 2C18)	*Palermo, M. R., and Poindexter, M. E., "Guidelines for Designing, Operating, and Managing Dredged Material Containment Areas," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.*
Brochure (Work Unit 2C17)	"Landscape Primer for Confined Dredged Material Disposal," prepared by Roy Mann Associates, under contract to U. S. Army Corps of Engineers.

DREDGED MATERIAL DENSIFICATION

(Task 5A: Disposal Operations Project)

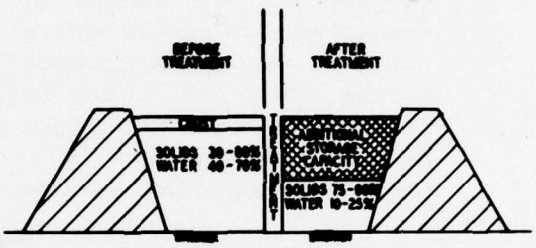


OBJECTIVE. . . . .

—to develop and test promising techniques for dewatering or densifying dredged material using mechanical, biological, and/or chemical techniques prior to, during, and after placement in containment areas—

APPROACH. . . . .

—to develop and test concepts through a three-phase program: I, literature and laboratory feasibility studies; II, field evaluation; and III, development of design alternative guidelines—



TYPICAL DISPOSAL AREA

IMPLEMENTATION. . . . .

—21 work units (5 contracts, 3 with cooperating CE elements, 13 in-house) involving total expenditure of $1,483,731.

—final results published in 12 in-house and contractor-prepared reports and 1 Synthesis Report.

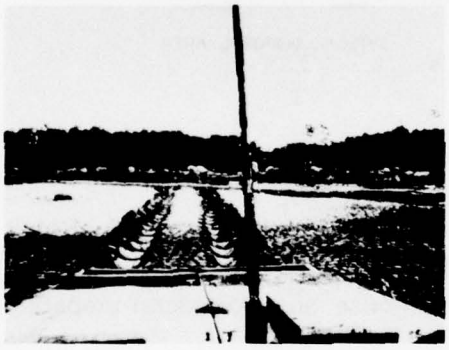
RESULTS. . . . .

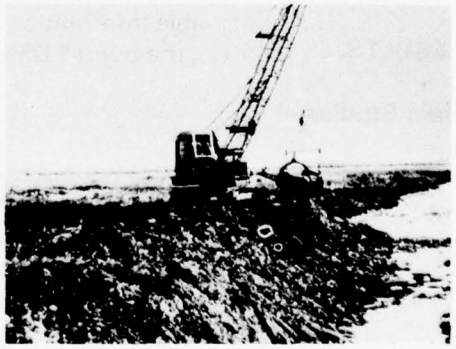
Field Studies—

Field studies were conducted at the Upper Polecat Bay Disposal Area in Mobile, Alabama, with the cooperation and assistance of the Mobile District. Progressive trenching, underdrains, low-voltage-gradient electroosmosis, vacuum wellpoints, periodic crust mixing, pressure-injected sand slurry drains, vegetation, and capillary wicks were all investigated to determine their potential as methods for dewatering dredged material. The methods produced various degrees of success in dewatering the dredged material. The two most promising techniques for general application are progressive trenching and underdrains.

Progressive Trenching—

Fine-grained dredged material placed in most confined disposal areas tends to remain at high moisture contents for extended periods, neither consolidating under its own weight nor drying. By trenching the surface of disposal areas to improve surface drainage, natural evaporative forces may be used to economically dry the dredged material back into solid form, resulting in a significant increase

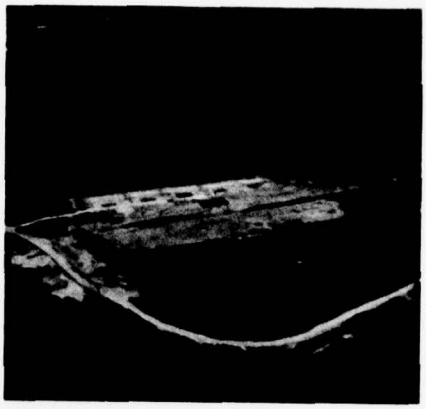




in available storage volume and providing a material suitable for dike raising or other productive uses. The key to trenching in the very soft dredged material is the Riverine Utility Craft or RUC. After a stable crust has been developed using the RUC, more conventional equipment may be used for trench deepening. (See TR DS-78-11.)

Underdrain Dewatering—

Large-scale test pits were constructed and filled with fine-grained dredged material to evaluate the effects of gravity and vacuum-assisted underdrainage and seepage consolidation as methods for dewatering dredged material. The results were very promising and an extension of the tests to simulate conditions within a specific



disposal area has been arranged. The extended scope of the tests will provide valuable information on the specific site as well as general information for the overall DMRP dewatering investigations. (See Work Unit 5A15.)

Phase III Studies—

All Phase III work units were completed and final guidelines for dewatering/densifying dredged material were published.

WORK UNITS. . . . .

5A01 Methodology for Dredged Material Reclamation and Drainage. Dames and Moore. $55,858. Report published as CR D-74-5.

5A02 Laboratory Study of Dredged Material Slurry Water Loss Due to Mechanical Agitation. EL, WES. $49,235. Report published as TR D-77-10.

5A03 State-of-the-Art Survey and Evaluation of Current Physical, Mechanical, and Chemical Dewatering and Densification Techniques. SPL, WES. $57,117. Report published as TR D-77-4.

5A04 A Laboratory Study to Determine the Variables that Influence the Electro-Osmotic Dewatering of Dredged Material. KMA Research Institute. $96,828. Published as part of field site report (TR D-78-59).

5A05 A Laboratory Study of Aeration as a Feasible Technique for Dewatering Fine-Grained Dredged Material. Environmental Engineering Consultants, Inc. $49,265. Report published as CR D-76-10.

5A06 Feasibility Study of General Crust Management as a Technique for Increasing Capacities of Dredged Material Containment Areas. Texas A&M University. $53,529. Report published as TR D-77-17.

5A07 Feasibility of Frost Action for Densification of Dredged Material. CRREL. $64,965. Report published as TR D-77-16.

5A08 Mobile (Alabama) Field Study. EL, WES. $91,000. Published as part of field site report (TR D-78-59).

5A09 Feasibility Study of Consolidating Fine-Grained Dredged Material with Windmill-Powered Vacuum Well Points. EL, WES. $126,000. Published as part of field site report (TR D-78-59).

5A10 Development of Capillary Enhancement Devices for Dewatering Fine-Grained Dredged Material. SPL, WES. $65,000. Published as part of field site report (TR D-78-59).

5A11 Feasibility of Injecting Fine-Grained Sand Slurry into Dredged Material. SPL and EL, WES. $15,000. Published as part of field site report (TR D-78-59).

5A12 Acquisition of Meteorological Data for Ongoing Dredged Material Research Studies at the Mobile Test Site. MESL, WES. $49,200. Published as part of field site report (TR D-78-59).

5A13 Containment Area Management as a Means of Promoting Densification of Fine-Grained Dredged Material. EL, WES. $54,064. Report published as TR D-77-19.

5A14 Mechanical Stabilization of Fine-Grained Dredged Material by Periodic Mixing in of Dried Surface Crust. MESL, WES. $33,000. Published as part of field site report (TR D-78-59).

5A15 Field Evaluation of Slurry Densification by Underdrainage Techniques. SPL, WES. $250,000. Published as part of field site report (TR D-78-59).

5A16 Development of Dewatering Alternatives Manual for the Mobile District. Mobile District. $25,000. Report published as MP D-77-3

5A17 Field Demonstration of Electro-Osmotic Dewatering of Fine-Grained Dredged Material Slurry. Mobile District. $109,558. Report published as MP D-77-2.

5A18 Vegetative Dewatering Field Demonstration. Dauphin Island Sea Lab. $56,583. Published as part of field site report (TR D-78-59).

5A19 Development of Containment Area Sizing Methodology Considering Effects of Dredged Material Dewatering. EL, WES. $55,000. Report published as TR D-78-41.

5A20 Implementation of Task 5A Technology. SPL, WES. $92,539. Data input to Work Unit 5A16.

5A21 Task 5A Design Alternatives Development–A Synthesis Report. EL, WES. $35,000. Report published as TR DS-78-11.

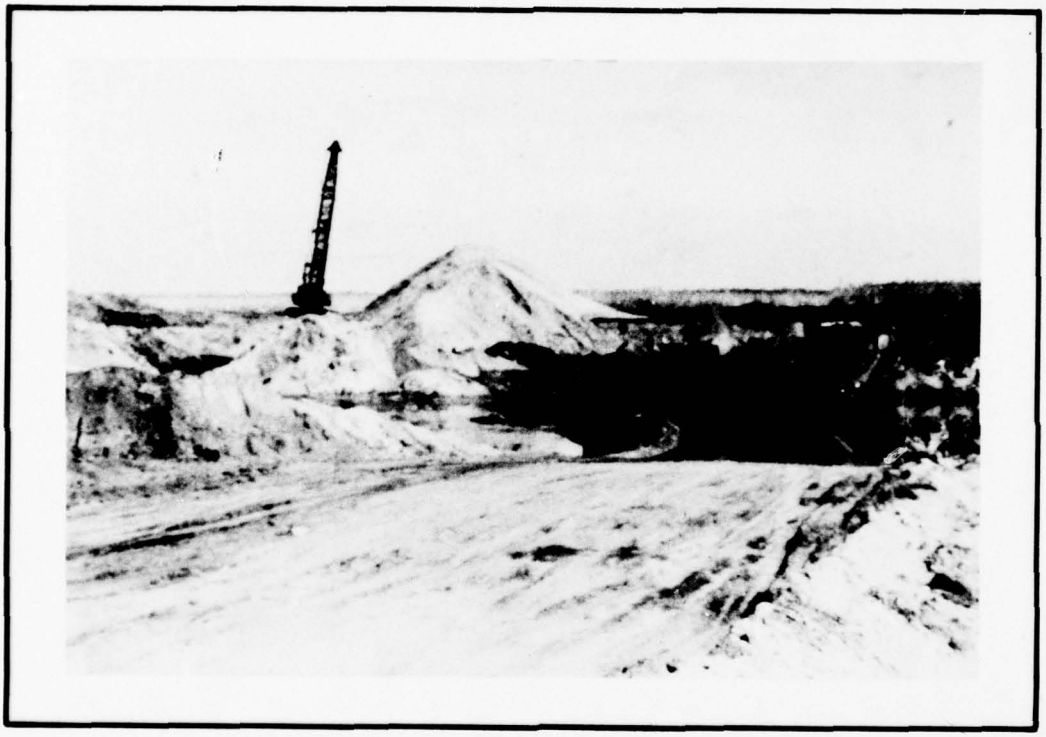
REPORTS PUBLISHED. . . . .

CR D-74-5 (Work Unit 5A01)	Garbe, C. W., Smith, D. D., and Amerasinghe, Sri., "Methodology for Dredged Material Reclamation and Drainage," November 1973, prepared by Dames and Moore, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A000 896.
CR D-76-10 (Work Unit 5A05)	Environmental Engineering Consultants, Inc., "Laboratory Study of Aeration as a Feasible Technique for Dewatering Fine-Grained Dredged Material," December 1976, prepared under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A035 673.
TR D-77-4 (Work Unit 5A03)	Johnson, S. J., et al., State-of-the-Art Applicability of Conventional Densification Techniques to Increase Disposal Area Storage Capacity," Soils and Pavements Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A041 452.
TR D-77-10 (Work Units 5A02, 5A14)	Haliburton, T. A., et al., "Effects of Mechanical Agitation on Drying Rate of Fine-Grained Dredged Material," September 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A044 843.
TR D-77-16 (Work Unit 5A07)	Chamberlain, E. J., and Blouin, S. E., "Freeze-Thaw Enhancement of the Drainage and Consolidation of Fine-Grained Dredged Material in Confined Disposal Areas," October 1977, prepared by Cold Regions Research and Engineering Laboratory under interagency agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. ADA 046 400.
TR D-77-17 (Work Unit 5A06)	Brown, J. W., and Thompson, L. J., "Feasibility Study of General Crust Management as a Technique for Increasing Capacity of Dredged Material Containment Areas," October 1977, Texas A&M Research Foundation, under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A047 509.

TR D-77-19 **(Work Unit 5A13)**	Bartos, M. J., Jr., "Containment Area Management to Promote Natural Dewatering of Fine-Grained Dredged Material," October 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A047 514.
MP D-77-2 **(Work Unit 5A17)**	O'Bannon, C. E., "Field Study to Determine the Feasibility of Electro-Osmotic Dewatering of Dredged Material," November 1977, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A048 566.
MP D-77-3 **(Work Unit 5A16)**	Haliburton, T. A., Douglas, P. A., and Fowler, J., "Feasibility of Pinto Island as a Long-Term Dredged Material Disposal Site," December 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 331.
TR D-78-41 **(Work Unit 5A19)**	Hayden, M. L., "Prediction of Volumetric Requirements for Dredged Material Containment Areas," August 1978, prepared by Oklahoma State University at Stillwater under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 481.
TR D-78-59 **(Work Units 5A04, 5A08, 5A09, 5A10, 5A11, 5A12, 5A14, and 5A15)**	Haliburton, T. A., ed., "Dredged Material Dewatering Field Demonstrations at Upper Polecat Bay Disposal Area, Mobile, Alabama," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.
TR DS-78-11 **(Work Unit 5A21)**	*Haliburton, T. A., "Guidelines for Dewatering/ Densifying Confined Dredged Material," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg Mississippi. NTIS No. AD A060 405.*

DISPOSAL AREA REUSE

(Task 5C: Disposal Operations Project)



OBJECTIVE. . . . .

—to investigate dredged material improvement and rehandling procedures aimed at permitting the removal of material from containment areas for landfill or other uses elsewhere—

APPROACH. . . . .

—develop and evaluate procedures for maintaining disposal areas convenient to dredging operations for indefinite periods while ensuring that disposal operations remain environmentally acceptable and operational; develop and evaluate disposal area reuse management practices to extend the capacity and useful life of dredged material disposal areas such that the need for new disposal areas is kept to a minimum—

IMPLEMENTATION. . . . .

—13 work units (5 in-house efforts, 6 contracts, 2 interagency agreements) involving a total expenditure of $807,905.

—final results published in 10 in-house and contractor-prepared technical reports, 3 special-purpose information transfer documents, and 1 Synthesis Report.

RESULTS. . . . .

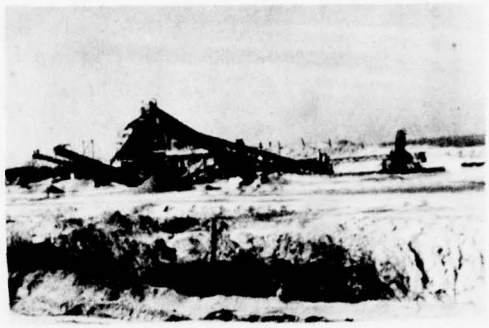
Present Practices—

Confining dredged material on land has changed little since inception; sites still have a short life span meaning that abandoned sites are proliferating and land requirements for new ones continue in the face of land scarcity, rising costs, and public objection. (See TR D-78-27.)

Disposal Area Reuse Management (DARM)—

The DARM concept was developed based on consultations with Corps Districts and results of DMRP research. Under this concept, the

disposal area is a collection and processing site where valuable portions of the dredged material are made available for productive uses while unusable material is, if necessary, treated and disposed of. (See MP D-76-15 and MP D-76-16.)



DARM Site Selection—

Reusable disposal sites represent a practical solution to the disposal site supply-and-demand problem. They appear to be a logical successor to the old-style, conventional disposal site which frequently has been selected, designed, and operated by rule-of-thumb rather than by sound engineering principles. Step-by-step procedures were developed for identifying the most economical reusable site location. These procedures provide the designer with the necessary information for selecting a reusable site appropriate for his long-term dredging needs. Early in the site selection process, it is important to identify any institutional, environmental, or social constraints to the reusable dredged material disposal site. (See TR D-78-22 and TR DS-78-12.)

Sedimentation Basin Design—

Sedimentation by gravity is the most economical method for suspended solids removal from dredged slurries. Therefore, a

methodology was developed specifically for designing fine-grained dredged material sedimentation basins. Laboratory studies and field investigations indicated that fine-grained dredged material sedimentation is controlled by either flocculant settling or by zone settling. Flocculant settling is prevalent in freshwater dredging environments, while zone settling is prevalent in saltwater dredging environments. Specific sedimentation basin design approaches were developed for these dredging environments. (See TR D-78-56 and TR DS-78-10.)

Engineering and Physical Properties—

Results showed that dewatered dredged material is a soil exhibiting engineering and physical properties similar to those of other natural soils. Most dredged material, when adequately dewatered, is acceptable landfill material. It is recommended that the Unified Soil Classification System be used in describing dredged material rather than by such negative terms as muck, spoil, sludge, or mud. (See TR D-77-18.)

The Reusable Site—

A reusable site is considered to be one where planning and operations are carried out to extend its life. Site reuse in its simplest form involves dewatering and densification of dredged material in containment areas by promoting natural drainage and drying processes, although more active dewatering concepts may be used. Additional measures may be taken to further extend capacity through removal of material from the site for productive uses. The reusable site concept is being implemented at the Mobile District Upper Polecat Bay Disposal Area. (See TR D-78-27 and TR DS-78-12.)

WORK UNITS. . . . .

5C01	Concept Development for Appurtenant Containment Area Facilities for Dredged Material Separation, Drying, and Rehandling. Hittman Associates. $94,968. Report published as CR D-74-6.
5C01A	Concept Development–Field Evaluation. Hittman Associates. $10,587. No report published.
5C02	Classification and Determination of Engineering and Other Physical Characteristics of Dredged Material. EL, WES. $94,424. Report published as TR D-77-18.
5C03	Systems Cost Analysis of Confined Disposal Practices. CERL. $81,687. No report published.
5C04	Study of Regional Landfill and Construction Material Needs in Terms of Dredged Material Characteristics and Availability. Green Associates, Inc. $66,793. Report published as CR D-74-2, Volumes I and II.
5C05	Development of Procedures for Selecting and Designing Reusable Dredged Material Disposal Sites. Acres American, Inc. $90,000. Report published as TR D-78-22.

5C06	Investigations of Legal, Policy, and Institutional Constraints Associated with Dredged Material Marketing and Land Enhancement. American Technical Assistance Corporation. $56, 653. Report published as CR D-74-7.
5C07	Feasibility Study of Vacuum Filtration Systems for Dewatering Dredged Material. Ryckman/Edgerly/ Tomlinson and Associates. $78,531. *Report published* as TR D-78-5.
5C08	Identification of Alternative Power Sources for Dredged Material Processing Operations. Naval Construction Battalion Center, Engineering Laboratory. $86,000. Report published as TR D-77-32.
5C09	Needs and Areas of Potential Application for Disposal Area Reuse Management (DARM). EL, WES. $46,710. Report published as TR D-78-27.
5C10	Physical Properties Investigation of In Situ WES Lake Dredged Material. EL, WES. $4,552. No report published.
5C11	*Methodology* for Design of Fine-Grained Dredged Material Containment Areas. EL, WES. $97,000. Report published as TR D-78-56.
5C12	Guidelines for Disposal Area Reuse–A Synthesis Report. EL, WES. Report published as TR DS-78-12.

REPORTS PUBLISHED. . . . .

CR D-74-2 **(Work Unit 5C04)**	Reikenis, R., Elias, V., and Drabkowski, E. F., "Regional Landfill and Construction Material Needs in Terms of Dredged Material Characteristics and Availability," Vols I and II, May 1974, prepared by Green Associates, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD 780 750 and AD 780 751.
CR D-74-6 **(Work Unit 5C01)**	Mallory, D. W., and Nawrocki, M. A., "Containment Area Facility Concepts for Dredged Material Separation, Drying, and Rehandling," October 1974, prepared by Hittman Associates, Inc., under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A002 605.

CR D-74-7
(Work Unit 5C06)
Wakeford, R. C., and MacDonald, D., "Legal, Policy, and Institutional Constraints Associated with Dredged Material Marketing and Land Enhancement," December 1974, prepared by American Technical Assistance Corporation under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A006 595.

MP D-76-15
Palermo, M. R., and Montgomery, R. L., "A New Concept for Dredged Material Disposal," February 1976, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A022 376.

MP D-76-16
Montgomery, R. L., and Palermo, M. R., "First Steps Toward Achieving Disposal Area Reuse," April 1976, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A024 646.

TR D-77-18
(Work Unit 5C02)
Bartos, M. J., Jr., "Classification and Engineering Properties of Dredged Material," September 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A047 768.

TR D-77-32
(Work Unit 5C08)
Parker, C. E., et al., "Identification of Alternative Power Sources for Dredged Material Processing Operations," November 1977. Prepared by Civil Engineer Laboratory, Naval Construction Battalion Center, under Interagency Agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A048 312.

TR D-78-5
(Work Unit 5C07)
Long, B. W., et al., "Feasibility Study of Vacuum Filtration Systems for Dewatering Dredged Material," February 1978. Prepared by Ryckman/Edgerley/Tomlinson & Associates, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A053 773.

TR D-78-22
(Work Unit 5C05)
Raster, T. E., et al., "Development of Procedures for Selecting and Designing Reusable Dredged Material Disposal Sites," June 1978. Prepared by Acres American Incorporated under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 422.

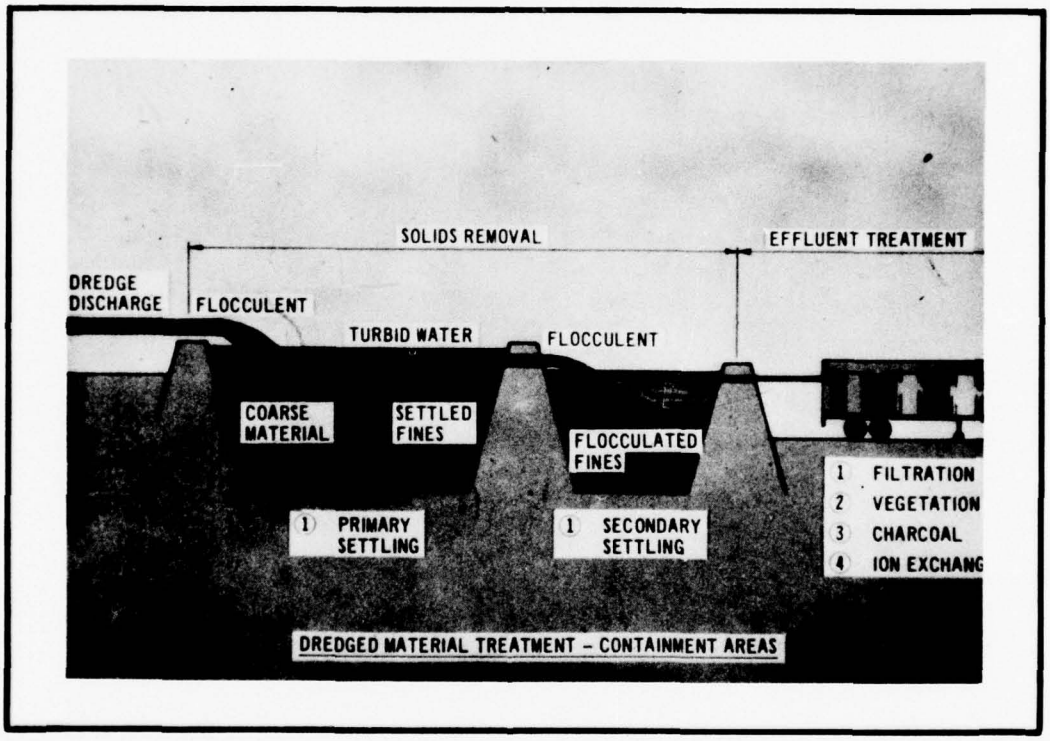
TR D-78-27
(Work Unit 5C09)
Palermo, M. R., "Needs and Areas of Potential Application of Disposal Area Reuse Management (DARM)," June 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A057 920.

TR D-78-56
(Work Unit 5C11)
Montgomery, R. L., "Methodology for Design of Fine-Grained Dredged Material Containment Areas," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

TR DS-78-12
(Work Unit 5C12)
Montgomery, R. L., et al., "Guidelines for Disposal Area Reuse," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

TREATMENT OF CONTAMINATED DREDGED MATERIAL

(Task 6B: Disposal Operations Project)



OBJECTIVE. . . . .

—to evaluate chemical, physical, and/or biological methods for the removal and recycling of dredged material constituents—

APPROACH. . . . .

—through laboratory and field investigations, develop methodologies, guidelines, and recommendations for treatment of dredged material to meet water quality criteria—

IMPLEMENTATION. . . . .

—7 work units (2 in-house efforts, 5 contracts) involving a total expenditure of $615,619.

—final results published in 6 in-house and contractor-prepared technical reports and 1 Synthesis Report.

RESULTS. . . . .

***Available Treatment Processes*—**

Results of a survey of conventional physical, chemical, and biological unit processes indicated that emphasis should be placed upon the physical/chemical processes as probably being the best treatment methods. Conventional biological treatment is generally ineffective because of the low soluble organic content of dredged material. (See Work Unit 6B01.)

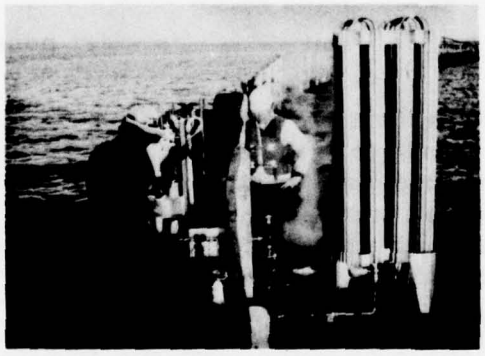
Laboratory Treatability Studies—

Laboratory studies were performed to determine the amenability of contaminated dredged material to treatment by physical or chemical processes. Results indicated that most conventional treatment techniques are not applicable or are impractical due to the relatively high solids content, low organic content, high flow rates, and variable nature of dredged material slurry. However, in-line oxygenation of dredged material slurry to reduce the dissolved oxygen sag in the water column during open-water pipeline disposal operations and chemical flocculation of fine-grained suspended material in the effluent from confined containment areas appear to warrant further evaluation. (See TR D-76-2.)

Oil and Grease Problems—

Oil and grease associated with dredged material slurry tend to remain tightly bound to the sediment particles and not readily released during dredging or disposal operations. It was found that relatively high oil levels in return waters were associated with high suspended solids concentrations. (See TR D-77-25.)

Oxygenation of Dredged Material—

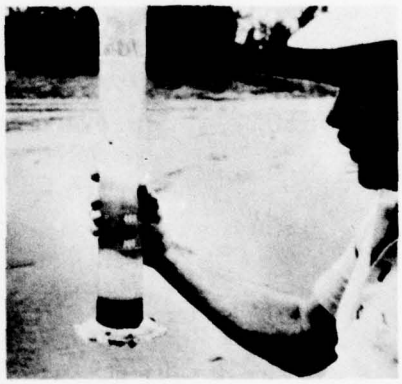


To alleviate the dissolved oxygen sag in the water column associated with open-water pipeline disposal operations, oxygen and air were injected directly into a dredge discharge. Dissolved oxygen levels in the water column within 60 m of the operation were raised two to three parts per million when pure oxygen was used to saturate the carrier water in the dredged material slurry. There was little apparent benefit from the injection of air. (See TR D-77-15.)

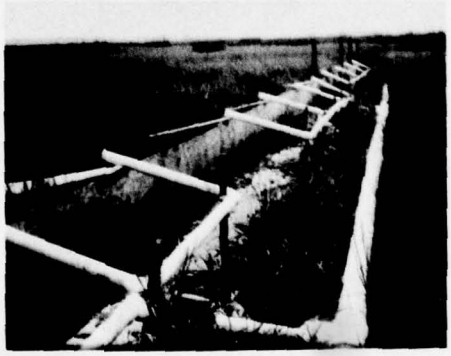
Chemical Coagulation Studies—

LABORATORY STUDIES. An extensive evaluation of various chemicals was performed to assess their potential for removing contaminants from dredged material by coagulation and subsequent sedimentation. Results indicated that chemical contaminants are usually associated with the fine-grained particles of the dredged material slurry. Flocculation of these suspended solids using polyelectrolytes is an effective means of removing both the suspended material and their associated contaminants from the effluent from dredged material containment areas. (See TR D-77-39 and TR D-78-54.)

DESIGN AND OPERATIONAL STUDIES. Laboratory and field investigations were performed to verify polyelectrolyte effectiveness. Procedures and guidelines for designing full-scale chemical treatment systems for disposal areas were established based on extensive jar tests and two pilot plant operations. (See TR D-78-54.)



Contaminant Removal with Vegetation—



One potential problem associated with large-scale upland disposal of dredged material is the possible degradation of adjacent waterways by discharging contaminated effluent. A salt marsh system was evaluated to determine its ability to remove contaminants from the effluent of a confined disposal area. Generally speaking, nutrients and heavy metals were removed from the effluent during overland flow through salt marshes primarily due to inorganic chemical processes which led to an accumulation of nutrients and metals in the salt marsh sediment. Removal occurred shortly after the

initial introduction of the effluent to the salt marsh, indicating that removal processes may be controlled largely by settling of the fine-grained dredged material suspended in the effluent and the formation of iron and manganese hydrous oxide precipitates that scavenge both nutrients and metals. (See TR D-77-37.)

WORK UNITS. . . . .

6B01 Assessment of Chemical, Physical, and Biological Processes for Treatment of Dredged Material. JBF Scientific Corporation. $41,900. No report published.

6B02 Laboratory Treatability Studies of Polluted Dredged Material. EL, WES. $125,772. Report published as TR D-76-2.

6B05 An Evaluation of Oil and Grease Contamination Associated with Dredged Material. Engineering-Science, Inc. $74,537. Report published as TR D-77-25.

6B06 *Research Study on Oxygenation* of Dredged Materials. JBF Scientific Corporation. $99,850. Report published as TR D-77-15.

6B07 Flocculation as a Means for Water-Quality Improvement from Disposal of Dredged Material in Confined Areas. University of Southern California. $112,580. Report published as TR D-77-39.

6B08 Development and Application of Design and Operational Procedures for Coagulation of Dredged Material Slurries and Diked Area Effluent. EL, WES. $74,700. Report published as TR D-78-54.

6B09 Field Verification of the Function Use of Vegetation to Remove Contaminating Constituents of Effluents from Dredged Material Disposal Areas. Dr. H. L. Windom. $86,280. Report published as TR D-77-39.

REPORTS PUBLISHED. . . . .

TR D-76-2
(Work Unit 6B02) Moore, T. K., and Newbry, B. W., "Treatability of Dredged Material (Laboratory Study)," February 1976, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A022 143.

TR D-77-15
(Work Unit 6B06)

Neal, R. W., Pojasek, R. B., and Johnson, J. C., "Oxygenation of Dredged Material by Direct Injection of Oxygen and Air During Open-Water Pipeline Disposal Operations," October 1977, prepared by JBF Scientific Corp. under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A046 482.

TR D-77-25
(Work Unit 6B05)

Engineering-Science, Inc., "An Evaluation of Oil and Grease Contamination Associated with Dredged Material Containment Areas," November 1977, prepared by Engineering-Science, Inc., under contract to U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A048 595.

TR D-77-37
(Work Unit 6B09)

Windom, H. L., "Ability of Salt Marshes to Remove Nutrients and Heavy Metals from Dredged Material Disposal Area Effluents," December 1977, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 643.

TR D-77-39
(Work Unit 6B07)

Wang, Chun-Ching, and Chen, K. Y., "Laboratory Study of Chemical Coagulation as a Means of Treatment for Dredged Material," December 1977, prepared by the Environmental Engineering Program, University of Southern California, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A050 596.

TR D-78-54
(Work Unit 6B08)

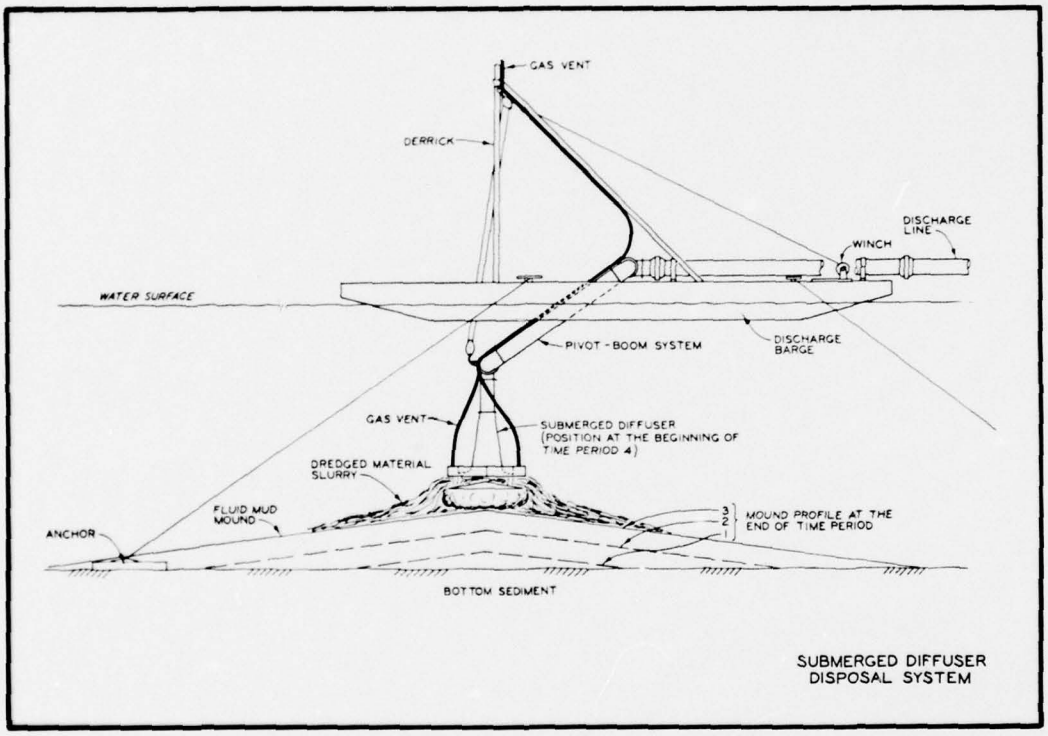
Jones, R. H., Williams, R. R., and Moore, T. K., "Development and Application of Design and Operation Procedures for Coagulation of Dredged Material Slurry and Containment Area Effluent," September 1978, Jones, Edmunds and Associates, Inc., and Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 060.

TR DS-78-14
(Task 6B)

Barnard, W. D., and Hand, T. D., "Treatment of Contaminated Dredged Material," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

TURBIDITY PREDICTION AND CONTROL

(Task 6C: Disposal Operations Project)



SUBMERGED DIFFUSER DISPOSAL SYSTEM

OBJECTIVE. . . . .

—to investigate the problem of turbidity and develop a predictive capability as well as physical and chemical control methods for employment in both dredging and disposal operations—

APPROACH. . . . .

—develop an empirical model based on field and laboratory data for predicting the nature of turbidity plumes generated by open-water pipeline disposal operations; evaluate, develop, demonstrate, and prepare guidelines for controlling turbidity at dredging and disposal operations—

IMPLEMENTATION. . . . .

—8 work units (1 in-house effort, 7 contracts) involving a total expenditure of $906,172.

—final results published in 7 in-house and contractor-prepared reports and 1 Synthesis Report.

RESULTS. . . . .

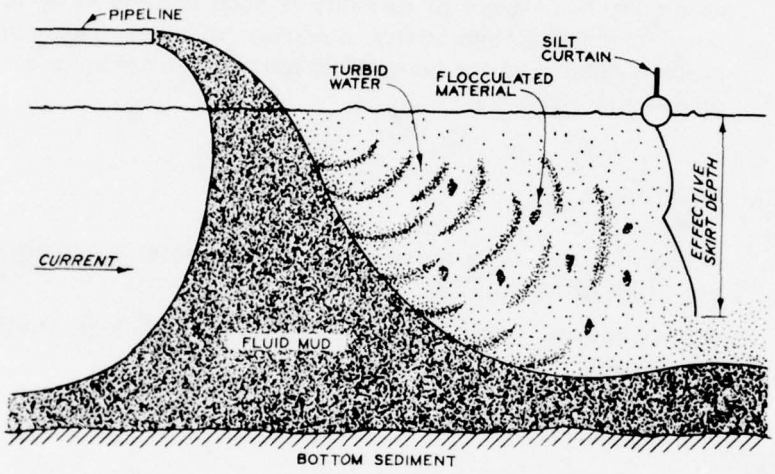
Operational Techniques—

Good dredging procedures, already known but not always practiced, will not only reduce dredge-induced turbidity but also will result in a more economical operation. Dredge-induced turbidity is normally restricted to the immediate vicinity of the dredge plant. (See CR D-76-4.)

Silt Curtains—

Silt curtains, when properly deployed and maintained, can be effective in controlling the dispersion of turbid water. Under quiescent conditions (current velocities less than 0.1 knot), turbidity levels

outside the curtain can be as much as 80 to 90 percent lower than the levels inside or upcurrent of the curtain. However, silt curtain effectiveness can be significantly reduced in high-energy regimes characterized by currents and turbulence. A current velocity of approximately 1 knot appears to be a practical limiting condition for silt curtain use. When silt curtains are used to surround open-water pipeline disposal operations, the vast majority of the dredged material slurry disposed within the curtained area forms a fluid mud layer on the bottom that flows out under the silt curtain. (See TR D-78-39.)



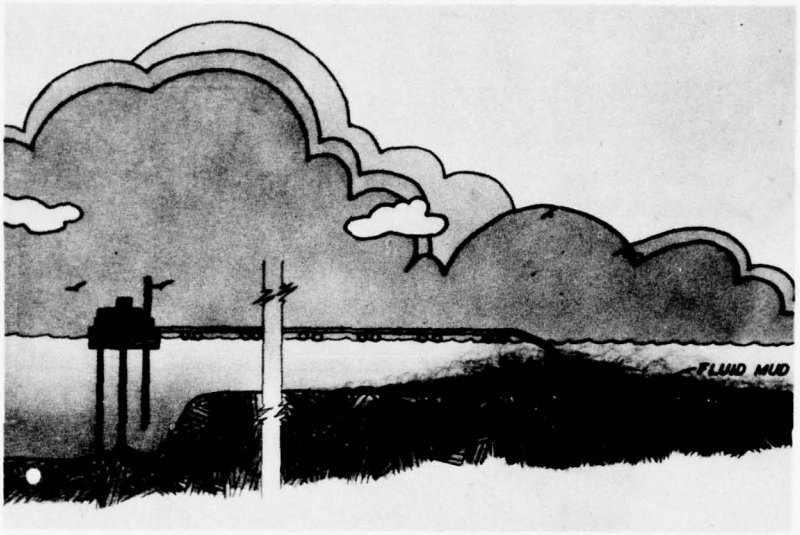
Laboratory Turbidity Study—

A detailed laboratory study of fine-grained sediment showed that the settling characteristics of dredged material suspensions are apparently controlled by the sediment concentration, the salinity of the water, and the percent organics in the sediment. (See TR D-77-14.)

Open-Water Pipeline Disposal—

Depending on the configuration of the pipeline at the discharge point, 95 to 99 percent of the disposed fine-grained dredged material slurry rapidly descends through the water column to the bottom of the disposal area where it accumulates around the discharge point in the form of a low-gradient (1:500) fluid mud mound. Suspended solids concentrations within the fluid mud layer typically range from 10 to

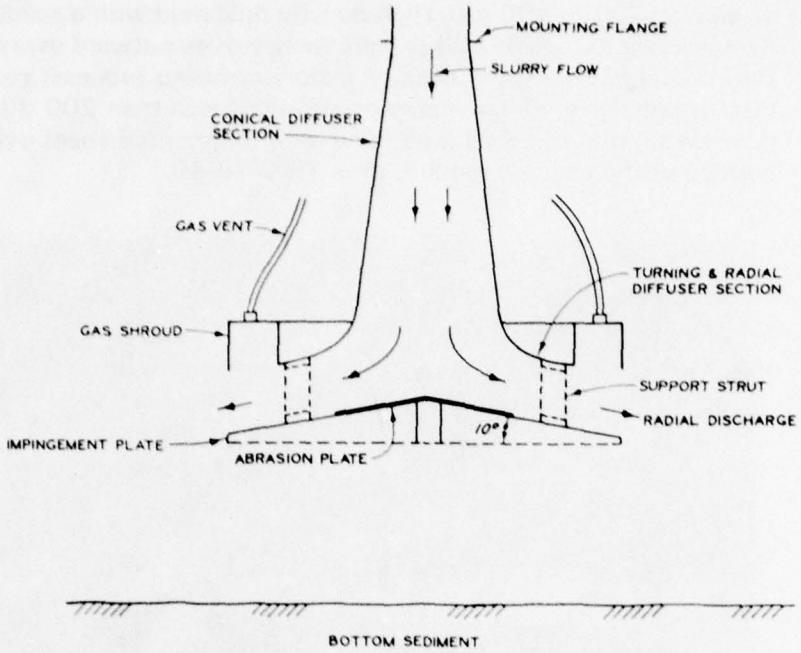
as high as 300 to 500 g/ℓ. High-density fluid mud with a solids concentration in excess of 200 g/ℓ probably moves outward away from the discharge point by means of a slow creeping process; recently discharged slurry with solids concentrations less than 200 g/ℓ may flow away from the discharge point as a fragmented sheet over the surface of the existing mound. (See TR D-78-40.)



The flow characteristics of the fluid mud depend primarily on the solids concentrations of the slurry and the bottom slopes within the disposal area. (See TR D-78-46.) A small percentage of the discharged dredged material slurry will remain suspended in the water column to form a turbidity plume. The characteristics of these plumes are controlled to a large extent by the size distribution of the dredged material, the discharge configuration, and the hydrodynamic regime at the disposal site. (See TR D-78-30.)

Submerged Discharge—

To minimize the upward mixing of turbid water into the water column at an open-water pipeline disposal operation, a diffuser can be used to control the dispersion of the discharged material by reducing the flow velocity of the slurry by a factor of 16. At the same time, the solids concentration of the slurry will be maintained so that the mounding of the fluid mud and dredged material can be maximized. (See TR D-78-44.)



SUBMERGED DISCHARGE DIFFUSER

WORK UNITS. . . . .

6C01 Laboratory Study Related to Predicting the Turbidity-Generation Potential of Sediments to be Dredged. Walden Research Division of ABCOR, Inc. $110,206. Report published as TR D-77-14.

6C02 Field Investigations of the Nature, Degree, and Extent of Turbidity Generated by Open-Water Pipeline Disposal Operations. State University of New York at Stony Brook. $197,863. Report published as TR D-78-30.

6C03 Investigation of Techniques for Reducing Turbidity Associated with Present Dredging Procedures and Operations. John Huston, Inc. $49,280. Report published as CR D-76-4.

6C04 Assessment of Chemical Flocculents and Friction-Reducing Agents for Application in Dredging and Dredged Material Disposal. SPL, WES. $33,430. No report published.

6C06 Analysis of Functional Capabilities and Performance of Silt Curtains. JBF Scientific Corporation. $123,281. Report published as TR D-78-39.

6C07 A Field Study of Fluid Mud Dredged Material: Its Physical Nature and Dispersal. Virginia Institute of Marine Science. $182,925. Report published as TR D-78-40.

6C08 An Evaluation of the Submerged Discharge of Dredged Material Slurry During Pipeline Disposal Operations. JBF Scientific Corporation. $109,925. Report published as TR D-78-44.

6C09 Laboratory Investigation of the Dynamics of Mud Flows Generated by Open-Water Pipeline Disposal Operations. JBF Scientific Corporation. $99,262. Report published as TR D-78-46.

REPORTS PUBLISHED. . . . .

CR D-76-4 (Work Unit 6C03) Huston, J. W., and Huston, W. C., "Techniques for Reducing Turbidity During Dredging Operations," May 1976, prepared by John Huston, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A026 623.

TR D-77-14 (Work Unit 6C01) Wechsler, B. A., and Cogley, D. R., "Laboratory Study Related to Predicting the Turbidity-Generation Potential of Sediments to be Dredged," November 1977, prepared by ABCOR, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A055 646.

TR D-78-30 (Work Unit 6C02) Schubel, J. R., et al., "Field Investigations of the Nature, Degree, and Extent of Turbidity Generated by Open-Water Pipeline Disposal Operations," July 1978, prepared by the Marine Sciences Research Center, State University of New York at Stony Brook, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 507.

TR D-78-39 (Work Unit 6C06) JBF Scientific Corporation, "An Analysis of the Functional Capabilities and Performance of Silt Curtains," July 1978, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A060 382.

TR D-78-40
(Work Unit 6C07)

Nichols, M. M., Thompson, G. S., and Faas, R. W. "A Field Study of Fluid Mud Dredged Material: Its Physical Nature and Dispersal," July 1978, prepared by Virginia Institute of Marine Science and Lafayette College under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 952.

TR D-78-44
(Work Unit 6C08)

Neal, R. W., et al., "Evaluation of the Submerged Discharge of Dredged Material Slurry During Pipeline Dredge Operations," August 1978, prepared by JBF Scientific Corporation under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 616.

TR D-78-46
(Work Unit 6C09)

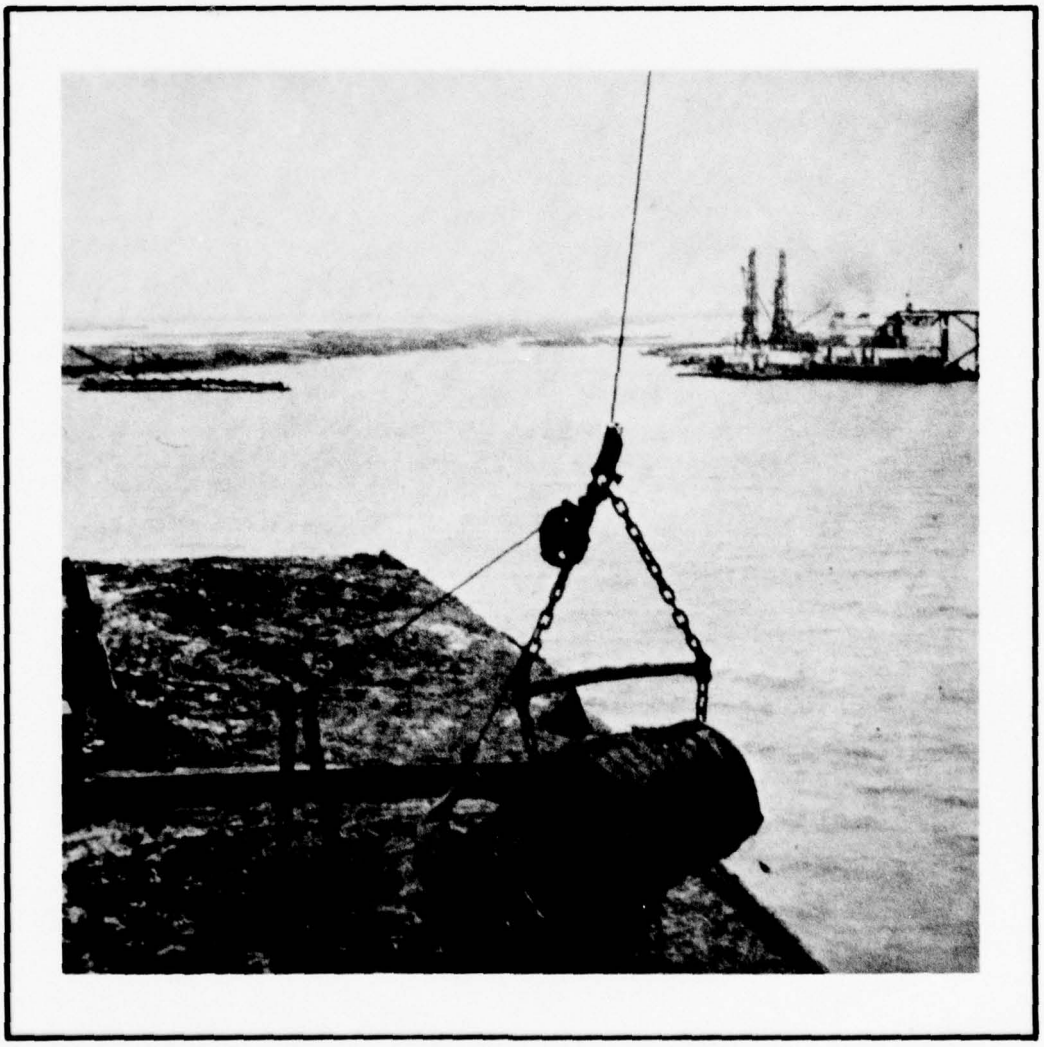
Henry, G., Neal, R. W., and Greene, S. H., "Laboratory Investigations of the Dynamics of Mud Flows Generated by Open-Water Pipeline Disposal Operations," August 1978, prepared by JBF Scientific Corporation under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 480.

TR DS-78-13
(Task 6C)

Barnard, W. D., "Prediction and Control of Dredged Material Dispersion Around Open-Water Pipeline Disposal Operations," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 573.

UPLAND DISPOSAL CONCEPTS DEVELOPMENT

(Task 3B: Productive Uses Project)



OBJECTIVE. . . . .

—to evaluate disposal alternatives such as using abandoned pits and mines and to investigate systems for the long-distance transport of dredged material to inland disposal areas—

APPROACH. . . . .

—develop comprehensive site-selection guidelines covering the technical, economic, and social considerations of inland disposal; develop the technical and economic information needed to consider the long-distance inland transportation of dredged material—

IMPLEMENTATION. . . . .

—2 work units (contracts) involving a total expenditure of $210,324.

—final results published in 2 contractor-prepared reports and 1 Synthesis Report combining the output from Tasks 3B and 4C.

RESULTS. . . . .

Literature Review—Inland Disposal—

Inland disposal of dredged material is feasible and sites can be designed and operated in a manner that is environmentally sound and socially acceptable. In those cases where the dredged material is heavily contaminated, solid waste disposal technology can be adapted for its disposal. A comprehensive checklist is included that is meant to be used as a decisionmaking tool by officials who must provide inland sites for disposal of dredged material. The checklist provides a step-by-step planning process for site selection and final site use. (See TR D-78-28.)

Transport Concepts—

Cost and "how to" data were developed for the long-distance transportation of dredged material by pipeline, barge, rail, truck, and conveyor systems. These data should offer sound information for planning and designing long-distance transport systems. Concept systems were developed for each transportation mode to guide planners and designers. (See TR D-77-33.)

WORK UNITS. . . . .

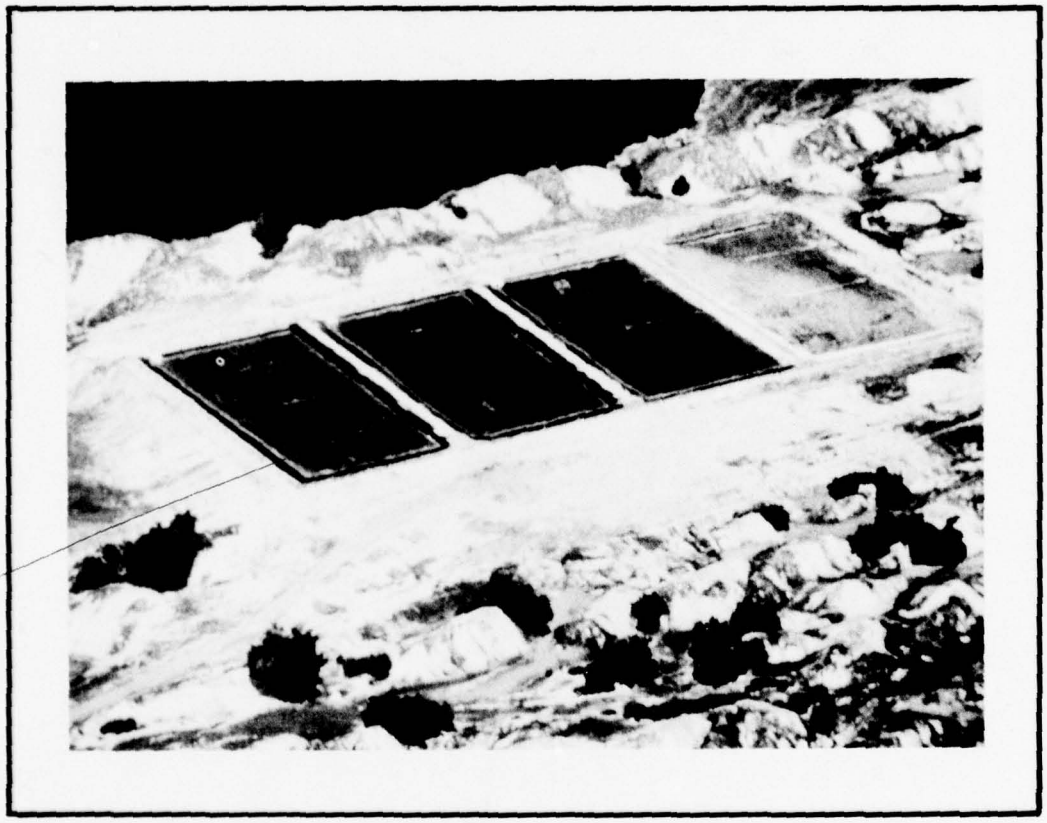
3B01	A Study of Dredged Material Transport Systems for Inland Disposal and/or Productive Uses Concepts. General Research Corporation. $166,851. Report published as TR D-78-28.
3B02	Feasibility of Inland Disposal of Dredged Material: Literature Review. SCS Engineers. $43,473. Report published as TR D-77-33.

REPORTS PUBLISHED. . . . .

TR D-77-33 (Work Unit 3B02)	SCS Engineers, "Feasibility of Inland Disposal of Dewatered Dredged Material; A Literature Review," December 1977, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A048 203.
TR D-78-28 (Work Unit 3B01)	Souder, P. S., et al., "Dredged Material Transport Systems for Inland Disposal and/or Productive Use Concepts," June 1978, prepared by the General Research Corporation under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A058 432.
TR DS-78-21 (Tasks 3B/4C)	*Spaine, P. A., Llopis, J. L., and Perrier, E. R., "Guidance for Land Improvement Using Dredged Material," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A067 195.*

LAND IMPROVEMENT CONCEPTS

(Task 4C: Productive Uses Project)



OBJECTIVE. . . . .

—to evaluate the use of dredged material as a resource for the development, enhancement, or restoration of land for agricultural or other uses—

APPROACH. . . . .

—consider dredged material as a valuable resource out of place or one for which a specific use has not been found; investigate various schemes to determine their potential for disposal use—

IMPLEMENTATION. . . . .

—6 work units (3 interagency agreements and 3 in-house efforts) involving a total expenditure of $469,387.

—final results published in 2 technical reports and 1 Synthesis Report that combines output from Tasks 3B and 4C.

RESULTS. . . . .

Laboratory Strip-Mine Study—

Subject to some constraints, dredged material can be used to reclaim strip-mined areas. However, before reclamation is done on a large scale, some small field experiments should be conducted. (See Work Unit 4C01.)

Use of Dredged Material in Solid Waste Management—

It is concluded that dredged material, especially dewatered material, can be used in solid waste management. The coarse-grained materials can be used for gas vents and leachate drains, whereas the fine-grained materials can be used for gas barriers, liners, and cover material. (See TR D-77-11.)

Dredged Material as an Agriculture Soil—

Fine-grained dredged material can be used as an agriculture soil or as an amendment to a relatively nonproductive soil. However, caution should be exercised if the dredged material contains high concentrations of salt or heavy metals. (See TR D-78-36.)

Strip-Mine Reclamation Field Demonstration—

It was demonstrated at Ottawa, Illinois, that fine-grained dredged material can be used to reclaim barren strip-mined land. Lush growth of both natural and planted vegetation presently exists on previously barren, acid-producing, strip-mined land. (See Work Units 4C04 and 4C05.)

Guidance for Land Improvement Using Dredged Material—

Guidance for the technical feasibility of enhancing nonproductive land with dredged material was produced for the following uses: as a soil for the reclamation of strip-mined land; as an agriculture soil and/or soil amendment; and in conjunction with solid waste management. (See Work Unit 4C06.)

WORK UNITS. . . . .

4C01	Use of Dredged Material to Reclaim Strip-Mined Land. A Preliminary Investigation. U. S. Bureau of Mines. $5,000. Results incorporated into Internal Working Document.
4C02	A Feasibility Study of Dredged Material Use in Conjunction with Solid Waste Management. EL, WES. $34,000. Report published as TR D-77-11.
4C03	Potential of Dredged Material as an Agricultural Soil and/or Amendment. Agricultural Research Service. $209,400. Report published as TR D-78-36.
4C04	Area Strip-Mine Reclamation Using Dredged Material: A Field Demonstration. EL, WES, and Chicago District. $125,987. Study continuing under Dredging Operations Technical Support.
4C05	Water Quality Analysis of Leachates. Argonne National Laboratory. $78,000. Continuing effort.
4C06	Guidance for Land Improvement Using Dredged Material. EL, WES. $17,000. Part of Synthesis Report TR DS-78-21.

REPORTS PUBLISHED. . . . .

TR D-77-11 **(Work Unit 4C02)**	Bartos, M. J., Jr., "Use of Dredged Material in Solid Waste Management," September 1977, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A045 509.
TR D-78-36 **(Work Unit 4C03)**	Gupta, S. C., et al., "The Agricultural Value of Dredged Material," July 1978, prepared by the Agricultural Research Service, North Central Region, U. S. Department of Agriculture, under Interagency Agreement with the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 298.
TR DS-78-21 **(Tasks 3B/4C)**	*Spaine, P. A., Llopis, J. L., and Perrier, E. R., "Guidance for Land Improvement Using Dredged Material," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A067 195.*

PRODUCTS DEVELOPMENT

(Task 4D: Productive Uses Project)

OBJECTIVE. . . . .

—to investigate the technical and economic aspects of the manufacture of marketable products—

APPROACH. . . . .

—determine what marketable commodities might be produced from dredged material or from the use of a disposal site—

IMPLEMENTATION. . . . .

—3 work units (contracts) involving a total expenditure of $267,664.

—final results published in 2 contractor-prepared reports.

RESULTS. . . . .

Lawn Sod—

Subject to certain constraints, commercial production of lawn sod, nursery products, foliage plants, and Christmas trees is feasible on mature disposal sites. On the other hand, production of horticultural crops on active disposal sites is not recommended. (See CR D-75-1.)

Mariculture as an Alternative—

A group of over 400 species of plants and animals were identified as potential subjects for mariculture in containment areas. Small-scale studies with shrimp showed no biological limitations to mariculture, and the only physical limitation seems to be harvesting in the very soft bottom sediments. Laboratory bioassay tests showed no mortality after 5 days in a wide range of sediments that included sediments from the Houston ship channel. (See Work Unit 4D02.)

Mariculture Field Demonstration—

The feasibility of shrimp mariculture in dredged material containment areas was demonstrated. Twenty acres of an existing 158-acre disposal site in Freeport, Texas, was diked off and stocked with approximately 700,000 juvenile shrimp. Results showed that even without feeding, shrimp growth was comparable to growth in a natural environment. (See TR D-78-53.)

WORK UNITS. . . . .

4D01	A Feasibility Study of Lawn Sod Production and/or Related Activities on Dredged Material Disposal Sites. Arthur D. Little, Inc. $39,566. Report published as CR D-75-1.
4D02	Investigation of Mariculture as an Alternative Use of Dredged Material Containment Areas. Dow Chemical Company. $94,572. Final results incorporated into Internal Working Document.
4D03	Demonstration of Marine Shrimp Culture in an Active Dredged Material Containment Area. Dow Chemical Company. $133,526. Report published as TR D-78-53.

REPORTS PUBLISHED. . . . .

CR D-75-1 **(Work Unit 4D01)**	A. D. Little, Inc., "A Feasibility Study of Lawn Sod Production and/or Related Activities on Dredged Material Disposal Sites," January 1975, prepared under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A006 609.
TR D-78-53 **(Work Unit 4D03)**	Quick, J. A., et al., "Field Demonstration of Shrimp Mariculture Feasibility in Dredged Material Containment Areas," August 1978, prepared by Dow Chemical U. S. A., Texas Division at Freeport, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A062 652.

DISPOSAL AREA
LAND-USE CONCEPTS

(Task 5D: Productive Uses Project)

OBJECTIVE. . . . .

—to assess the technical and economic aspects of the development of disposal areas as landfill sites and to develop recreation-oriented and other public or private land-use concepts—

APPROACH. . . . .

—investigate issues associated with creating shoreline or offshore recreational areas, compare case studies of productive land-use issues, evaluate legal/regulatory impacts, develop created-land valuation techniques, compile handbook for productive land-use implementation—

IMPLEMENTATION. . . . .

—6 work units (5 contracts involving an aggregate expenditure of $621,706; 1 in-house work unit).

—final results published in 4 contractor-prepared reports and 1 Synthesis Report.

RESULTS. . . . .

Creation of Recreation Land—

Dredged material can be used in an economically efficient manner to create recreational land in urban areas. Environmental concerns are not an insurmountable barrier; however, financial resources available to local communities to develop the recreational potential of disposal sites may be the most significant constraint. An econometric model was proposed that will allow planners to assess recreational area needs and potential value. The initiative and attitude taken by the Corps, in concert with local or regional planners, toward recreational use of dredged material will determine in many cases the extent of implementation. (See CR D-76-6.)

Case Studies and Comparative Analyses—

This research effort consisted of a detailed study of 12 selected cases where dredged material from navigation projects was used to create land. The study identified issues that were raised during the projects, why some issues were more important than others, and how the issues were addressed. Also identified were elements or physical features that affect the feasibility of disposal or productive land-use plans. The issues and elements documented during the study were distilled into factors that govern the implementation of dredged material land-use concepts. Along with the discussion of issues, the study identified important land-use planning principles needing consideration during any dredged material land-use project. (See TR D-77-43.)

Legal/Regulatory Impacts—

Federal, State, and local laws and regulations were identified and evaluated to determine the legal framework within which the Corps must work to accomplish successful land use of dredged material containment areas. (See TR D-78-55.)

Determining Land Values of Dredged Material Containment Areas—

A framework methodology was developed that can be used by planners and engineers to predict the value of a proposed land use of dredged material containment areas. (See TR D-78-19.)

Land-Use Implementation Guidelines—

The guidelines are aimed at the planning and implementation considerations and are a synthesis of the relevant information produced in the previous research efforts. Many of the findings are in terms of general planning considerations that should be of concern to all disciplines. The considerations presented are those viewed as most important for the success of a productive land-use project of a dredged material containment area. (See TR DS-78-20.)

WORK UNITS. . . . .

5D01 Socio-Economic Aspects of Dredged Material Disposal: Creation of Waterfront Recreational Opportunities in Urbanized Areas. University of Virginia. $163,817. Report published as CR D-76-6.

5D02 Case Studies and Comparative Analyses of Issues Associated with Productive Land Use at Dredged Material Disposal Sites. Energy Resources Company, Inc. $297,381. Report published as TR D-77-43.

5D03 Productive Land Use of Dredged Material Containment Areas: International Literature Review. Beeman/Benkendorf and WES, EL. $29,097. Report published as MP D-78-4.

5D04 Evaluation of Laws and Regulations Impacting the Land Use of Dredged Material Containment Areas. Science Applications, Inc. $73,050. Report published as TR D-78-55.

5D05 Determination of Value of Land and Associated Benefits Created by Dredged Material Containment. SCS Engineers. $58,361. Report published as TR D-78-19.

5D06 Guidelines for Productive Land Use of Dredged Material Containment Areas. EL, WES. Report published as TR DS-78-20.

REPORTS PUBLISHED. . . . .

CR D-76-6
(Work Unit 5D01)
Skjei, S. S., "Socio-Economic Aspects of Dredged Material Disposal: Creation of Waterfront Recreational Opportunities in Urbanized Areas," May 1976, prepared by University of Virginia under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A027 554.

TR D-77-43
(Work Unit 5D02)
Gushue, J. J., and Kreutziger, K. M., "Case Studies and Comparative Analyses of Issues Associated with Productive Land Use of Dredged Material Disposal Sites; Volume I: Main Text and Volume II: Appendices A-R," December 1977, prepared by Energy Resources Company, Inc., and Sasaki Associates, Inc., under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A055 386 (Volume I) and AD A054 893 (Volume II).

TR D-78-19
(Work Unit 5D05)
Conrad, E. T., and Pack, A. J., "A Methodology for Determining Land Value and Associated Benefit Created from Dredged Material Containment," June 1978, prepared by SCS Engineers under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A061 841.

TR D-78-55
(Work Unit 5D04)
Cole, J., and Brainard, M., "Evaluation of Laws and Regulations Impacting the Land Use of Dredged Material Containment Areas," September 1978, prepared by Science Applications, Inc., Environmental Sciences Division, under contract to the U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A063 905.

TR DS-78-20
(Work Unit 5D06)
Walsh, M. R., and Malkasian, M. D., "Productive Land Use of Dredged Material Containment Areas," December 1978, Environmental Laboratory, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi.

MP D-78-4
(Work Unit 5D03)
Environmental Laboratory and Beeman, O., and Benkendorf, A. P., "Land Use of Dredged Material Containment Areas: Productive Use Examples," August 1978, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A059 723.

RESEARCH RESULTS
APPLICATIONS

(DMRP Task 9A)

OBJECTIVE. . . . .

—to ensure the timely application of the results of the DMRP in project planning, design, implementation, and regulation through the effective dissemination of information within the Corps and to all relevant outside groups—

APPROACH. . . . .

—design and implement an intensive and extensive effort in information dissemination and technology transfer; assess the effectiveness of various components of the effort; plan the nature and mode of implementation of concluding DMRP summary and synthesis documents—

IMPLEMENTATION. . . . .

—2 work units (contracts) involving a total expenditure of $272,940.

—extensive staff effort and publications program involving a total expenditure of $1,172,129.

RESULTS. . . . .

Past Activities—

A balanced effort was accomplished, consisting of a mixture of formal publications and printed materials, Corps directives and manuals, and interpersonal contacts in the form of briefings/workshops/seminars. All were designed based upon feedback from Corps personnel and other information users gathered through direct interviews.

Future Activities—

Following completion of the DMRP in March 1978, efforts to promote even greater results application were initiated via a WES technical support team established for the purpose of assisting Corps field elements and OCE. Designated the Dredging Operations Technical Support (DOTS) team, this OCE-sponsored activity will continue as long as it is needed and effective.

WORK UNITS. . . . .

9A01 Information Dissemination and Technology Transfer System for the Dredged Material Research Program. Teknekron, Inc. $146,783. Report published as CR D-77-1.

9A02 Design and Development of an Index and Retrieval System for Dredged Material Research Program Results. Herner and Co. $126,157. Report published as TR DS-78-23.

REPORTS PUBLISHED. . . . .

CR D-77-1 *(Work Unit 9A01)* Speaker, D. M., and Weisgerber, W. H., "Design Requirements for an Information Dissemination and Technology Transfer System for the Dredged Material Research Program," February 1977, U. S. Army Engineer Waterways Experiment Station, Vicksburg, Mississippi. NTIS No. AD A038 886.

APPENDIX A

THE DMRP CONTRACTORS. . . . .

ABC Laboratories, Inc., Columbia, Missouri (G. Brookhart)

Acres American, Inc., Buffalo, New York (D. W. Lamb)

Adriaan Volker Dredging Company, Rotterdam, The Netherlands (A. J. Hoekstra and K. d'Angremond)

Agricultural Research Service, North Central Region, St. Paul, Minnesota (W. E. Larson)

American Technical Assistance Corp., McLean, Virginia (D. McDonald)

Argonne National Laboratory, Argonne, Illinois (W. Harrison)

Arthur D. Little, Inc., Cambridge, Massachusetts (F. W. Besley and J. Harrison)

Battelle Columbus Laboratories, Columbus, Ohio (R. Moore)

Beeman/Benkendorf j.v., Portland, Oregon (O. Beeman and A. Benkendorf)

Biological Water Purification, Inc., New York, New York (L. Banks)

Brian J. Gallagher and Co., Milwaukee, Wisconsin (B. J. Gallagher)

University of California Bodega Marine Laboratory, Bodega Bay, California (C. Hand and R. Peddicord)

The University of California at Davis, Davis, California (R. B. Krone)

The Center for the Environment and Man, Inc., Hartford, Connecticut (D. R. Zoellner)

The Citadel, Charleston, South Carolina (W. B. Ezell, Jr.)

Coastal Ecosystems Management, Fort Worth, Texas (R. Parker)

Coastal Engineering Research Center, Corps of Engineers, Ft. Belvoir, Virginia (J. Eckert)

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Executive overview and detailed summary; Dredged Material Research Program / [by Roger T. Saucier ... et al.]. Vicksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1978.
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